

WORLD TRADE CENTER RESIDENTIAL DUST CLEANUP PROGRAM

Draft Final Report

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Note:

This interim final report is a working document that will be subject to further Agency and third-party review. EPA intends to excerpt, and possibly expand, portions of this report for inclusion in manuscripts that will be submitted to scientific journals for review and consideration for publishing.

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GLOSSARY

Average residence dust lead (dioxin) loading: The arithmetic mean of the results from multiple (typically three) dust wipe samples that were collected from each residence before (i.e., pre-cleanup dust lead/dioxin loading) and after (i.e., post-cleanup dust lead/dioxin loading) cleaning.

Centrographic statistics: The two dimensional counterparts to the traditional univariate statistics that are used to describe the location (e.g., mean, median) and dispersion (e.g., standard deviation) of a single variable. Centrographic statistics are used to describe the geographic center of a collection of objects, their distribution in space, and the orientation of the distribution; e.g., buildings with PCMe exceedances.

Clean and test buildings: Buildings that contain one or more residences or common areas that were cleaned and then tested for airborne asbestos; a subset of these residences were also tested for metals and dust dioxin loading (mass/unit area). Many *clean and test* buildings also contain residences that were tested but not cleaned, at the request of the residents.

Clean and test data: Consists of the results of samples collected from residences and common areas that were cleaned and then tested for airborne asbestos; a selected subset of the residences was also tested for dust lead loading and dust dioxin loading.

Common areas: Areas of residential buildings that are accessible to all building occupants; e.g., hallways, laundry rooms, stairwells.

Count data: A type of categorical data that represent the number of times something occurs within an interval of time, space or volume; e.g., the number of PCMe exceedance within the potentially effected area surrounding the WTC site.

CSR: Complete spatial randomness

Dust dioxin loading: Nanograms of dioxin per square meter of sampled surface (ng/m^2).

Dust dioxin loading exceedance: Dust dioxin loadings that exceed the health-based benchmark of $2 \text{ ng}/\text{m}^2$.

Dust lead loading: Micrograms of lead per square foot of sampled surface ($\mu\text{g}/\text{ft}^2$).

Dust lead loading exceedance: Dust lead loadings that exceed the HUD screening level of $25 \mu\text{g}/\text{ft}^2$.

Dust wipe samples: Samples of residential dust that were collected from residences and common areas. Samples were typically collected from three different surfaces within an apartment (e.g., walls, floors, counter tops).

Nearest neighbor distance (NNd): Used in the point pattern analysis to assess the spatial distribution of PCMe exceedance. The NNd is the average distance between a PCMe exceedance and the closest other PCMe exceedance. The NNd is compared against the distance that is expected if the PCMe exceedances are randomly distributed in space. Values less than the expected distance indicate spatial clustering, values greater than the expected distance indicate dispersion.

PCMe: Asbestos phase contrast microscopy equivalent (PCMe) concentrations measured by TEM. Phase Contrast Microscopy equivalence (PCMe) is a process to identify asbestos fibers by TEM analysis that would also be visible by PCM.

PCMe exceedance: PCMe results that exceeded the health-based benchmark of 0.0009 fibers per cubic centimeter (f/cc) of air.

Point pattern analysis: A statistical analysis in which the emphasis is on the *location* of events (e.g., PCMe exceedance), rather than the magnitude of the data (e.g., PCMe concentration). The focus of point pattern analysis is often to test the null hypothesis of complete spatial randomness (CSR) (i.e., the distribution of events follow a homogeneous spatial Poisson process). The nonparametric hypothesis of *spatial randomness* is also tested in this report, using computer simulation methods.

Poisson distribution (Poisson model): Used to describe the occurrence of rare events. The Poisson distribution is used throughout this report to describe the distribution of PCMe exceedances. The Poisson distribution is typically used to model the occurrence of an event during a fixed period of time or within a fixed region of space.

Positive spatial autocorrelation: The tendency for samples collected near each other to have similar values.

Ripley's K function: Used in the point pattern analysis to assess the spatial distribution of PCMe exceedance. Ripley's K function counts the number of other events that occur within a certain distance of an event. The count is repeated for each event. Ripley's K function equals the sum of the counts. Typically, Ripley's K function is calculated for several distance intervals and the values are plotted versus the distance intervals. Values greater than zero indicate spatial clustering, values less than zero indicate dispersion.

Spatial autoregression: A type of statistical regression analysis that considers, explicitly, the spatial autocorrelation exhibited by the data, if any.

Spatial clustering: The tendency for PCMe exceedance to be spaced closer together than is likely if the exceedances were randomly distributed in space (i.e., randomly distributed among the sampled buildings).

Spatial dispersion: The tendency for PCMe exceedance to be spaced further apart on average than is likely if the exceedances were randomly distributed in space (i.e., randomly distributed among the sampled buildings). A square grid is an example of a spatial dispersion.

Spatial resolution: Refers to the coarseness of geographic aggregation. In this report, PCMe data are analyzed at two levels of spatial resolution: at the building level and at the statistical summary area (SSA) level.

Spatial scale: Refers to the geographic extent over which an analysis is performed. In this report, the spatial scale is Lower Manhattan, south of Canal Street.

TEM: Transmission electron microscopy; an analytical method to identify and count the number of asbestos fibers present in a sample.

Test only buildings: Buildings that contain one or more residences that were tested for one or more of the following: airborne asbestos, dust lead loading, dust dioxin loading, but were not cleaned, at the request of the residents. Most *test only* buildings also contain residences or common areas that were cleaned and tested.

Test only data: Results of samples collected from residences that were tested for one or more of the following: airborne asbestos, dust lead loading, dust dioxin loading, but were not cleaned, at the request of the residents.

Unique *test only* buildings: Buildings that contain one or more residences that were tested for one or more of the following: airborne asbestos, dust lead loading, dust dioxin loading, but were not cleaned, at the request of the residents. Unique *test only* buildings do ***not*** contain residences or common areas that were cleaned and tested.

DRAFT

ACRONYMS

PCMe	phase contrast microscopy equivalent
TEM	transmission electron microscopy
CV	coefficient of variation
TEQ	toxicity equivalent quotient
SSAs	statistical summary areas
iid	independent and identically distributed
NNd	nearest neighbor distance
NNI	nearest neighbor index
N	total number of events
A	area of the site
CSR	complete spatial randomness
CI	confidence interval
S-W statistic	Shapiro-Wilk statistic
f/cc	fibers/cubic centimeter
$\mu\text{g}/\text{ft}^2$	micrograms per square foot
ng/m^2	nanograms per square meter

Executive Summary

Introduction and Background

This report presents and summarizes the results of EPA's World Trade Center Dust Cleanup and Testing. Under the authority of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act), EPA formed an Indoor Air Task Force in February 2002. In April 2002, the Mayor of the City of New York requested that EPA serve as the lead agency for addressing potential effects of WTC dust on residences in lower Manhattan. EPA subsequently developed and implemented a comprehensive program, with broad interagency input at federal, state and local levels, to ensure that lower Manhattan residents were protected from potential exposures to WTC-related dust and debris.

The WTC dust cleanup and testing program allowed residents living south of Canal Street in lower Manhattan to have their homes professionally cleaned and tested or just tested free of charge. In addition to offering this service to residents, EPA conducted three supporting projects, also funded by FEMA under the Stafford Act. The projects were:

- A Contaminants of Potential Concern (COPC) Report established health-based benchmarks for contaminants in support of cleanup efforts.
- A Confirmation Cleaning Building Study evaluated the effectiveness of various cleaning techniques on WTC-related dust.
- A Background Study provided data on contaminants in indoor air and settled dust in residences North of 78th Street.

Overview of WTC Dust Cleanup and Testing Program

All residents of lower Manhattan living below Canal Street were given a choice of services. Residents could choose to have their residence professionally cleaned, followed by confirmatory testing, or they could choose to just have their homes tested. Certified professional contractors cleaned and tested the homes, under the direction of EPA. Owners and managers of residential buildings and coop boards could also have their building's common areas cleaned and HVAC system evaluated and cleaned, if necessary. The cleaning and monitoring contractors cleaned and tested common areas such as the building lobby, hallways, stairways and elevator interiors. The contractors evaluated other common areas, including laundry rooms, utility rooms, compactor rooms, and elevator shafts and cleaned as needed.

Residences were cleaned using standard asbestos cleanup methods – using HEPA-filtered vacuums and wet wiping all horizontal hard surfaces (i.e. floors, ceilings, ledges, trims, furnishings, appliances, equipment, etc.). Vertical and soft surfaces were HEPA vacuumed two times. EPA did not require

workers to wear personal protection equipment during these routine cleanups because OSHA determined that such equipment was not necessary. As an added precaution, contractors isolated the areas containing visible dust and wore personal protection equipment.

Depending upon the size of the residence, from three to five air samples were collected and analyzed for asbestos using transmission electron microscopy (TEM) and phase contrast microscopy (PCM). In a subset of the residences, pre- and post-cleanup dust wipe samples were collected (e.g., from floors, walls, and furniture) and analyzed for dioxin, mercury, lead, and 21 other metals. The results of this sampling, along with interpretation through a comparison with health-based benchmarks, were shared with occupants of the residences. Residences that did not meet the health-based benchmark of 0.0009 fibers per cubic centimeter for asbestos in one or more samples were encouraged to have their residences re-cleaned and tested until they met the benchmark. In a few cases, residents chose not to have their residences re-cleaned. There were a number of outcomes that resulted in inconclusive results. Filter overload was the most common. Filter overload occurs when too many dust particles are captured on the filter. The filter becomes obscured so technicians examining it under a microscope cannot separate out individual fibers. This causes an inconclusive result, which is discarded. Other causes of inconclusive results are blown or damaged filters. Residents with more than one inconclusive result were encouraged to have their apartments re-cleaned and re-tested. A total of 28,702 valid sample results were analyzed, 22,497 from residential units and 6,205 from common areas within residential buildings (e.g., hallways, laundry rooms).

Results

Asbestos

The number of samples that exceeded the health-based benchmarks for airborne asbestos was very small – about 0.4% of the asbestos samples taken. In those cases where the benchmark was exceeded in both residences and in common spaces, the cleanup program was successful in achieving the health-based benchmark for asbestos after the first cleaning approximately 99% of the time.

Wipe Samples

Contractors collected wipe samples from 263 apartments in 156 buildings. Approximately 14% of the pre-cleanup samples exceeded the U.S. Housing and Urban Development (HUD) screening level of 25 $\mu\text{g}/\text{ft}^2$, while only about 3% of the post-cleanup samples exceeded the screening level. This showed that the cleanup methods were effective in reducing lead. The percent of apartments that exceeded the lead health-based benchmark was greater than the percentages of apartments that had exceedances for other metals, mercury and dioxin. The level was consistent, however, with data from the HUD on housing

stock in the Northeast United States. This factor makes it difficult to distinguish between lead from World Trade Center dust and other sources, especially in older buildings.

There were very few exceedances of the health-based screening values measured for any of the other 22 metals. The screening value of $627 \mu\text{g}/\text{m}^2$ for antimony was exceeded in 2 pre-cleanup samples (0.1% of all samples); the maximum measured value was $1,180 \mu\text{g}/\text{m}^2$. The screening value of $157 \mu\text{g}/\text{m}^2$ for mercury was exceeded in 5 pre-cleanup samples (0.4% of all samples).

Reductions in dust dioxin loadings were modest due to the low pre-cleanup levels. Only 8 of the 1,535 (approximately 0.5%) of the combined samples (i.e., *test only* and *clean and test*) exceeded the health-based benchmark for residential dust dioxin loading of $2 \text{ ng}/\text{m}^2$.

An analysis of the location of asbestos exceedances does not demonstrate a special pattern of exceedances relative to WTC proximity. Apparent groups of asbestos exceedances could be explained by the location of the sampled buildings and the variability in the number of samples that were collected from each building.

1.0 Introduction

The U.S. Environmental Protection Agency (EPA) supported federal, state, and New York City efforts to recover from the federally declared disaster resulting from the September 11, 2001 attack on the World Trade Center (WTC). These actions were taken under the authority of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act) and in accordance with the applicable procedures and policies of the National Oil and Hazardous Substance Pollution Contingency Plan, 40 C.F.R. Part 300 (the NCP) (EPA, 1990). This report provides a summary of the actions taken by EPA to cleanup the indoor environment in Lower Manhattan.

The cleanup of the WTC site and surrounding ambient (i.e., outdoor) environment proceeded through the winter of 2001-2002. Early investigations indicated that an indeterminate number of residences located in the vicinity of the WTC complex were contaminated with dust and debris following the WTC attack; and there was growing concern in the re-occupied residential communities of Lower Manhattan regarding potential long-term health problems associated with residual WTC-related indoor dust (Figure 1-1). EPA formed an Indoor Air Task Force in February, 2002 and by request of the Mayor of the City of New York, EPA was designated the lead governmental agency for addressing the indoor environment in April, 2002. EPA's focus in this regard was to address indoor air concerns through an indoor dust cleanup and air sampling program for residential spaces in Lower Manhattan. This comprehensive program was implemented to ensure that Lower Manhattan residents were protected from potential exposures to harmful dust and debris residuals. EPA developed this program with broad interagency input at federal, state and local levels. EPA utilized all the tools available, including appropriate aspects of the NCP, to achieve this goal as expeditiously as possible.

EPA implemented three programs related to indoor air in Lower Manhattan residences. These programs were funded by FEMA under the Stafford Act, specifically Sections 403 (Essential Assistance) and 407 (Debris Removal) (Figure 1-2). First, EPA directed a Confirmation Cleaning Building Study (EPA, 2003a) by collecting samples in a building that had only minimal cleaning after the attack, employing and evaluating various cleaning techniques on WTC-related dust. Second, EPA directed a Background Study (EPA, 2003b) to provide monitoring data on indoor air contaminants in residences north of 78th Street, which were minimally affected by the collapse of the WTC, so that such data could be compared with data obtained in residences in Lower Manhattan. Third, EPA, along with the New York City Department of Environmental Protection (NYCDEP), provided for the monitoring and cleaning of Lower Manhattan residences through the Indoor Air Residential Assistance Program-WTC Dust Cleanup. Under this

Figure 1-1. Site location map



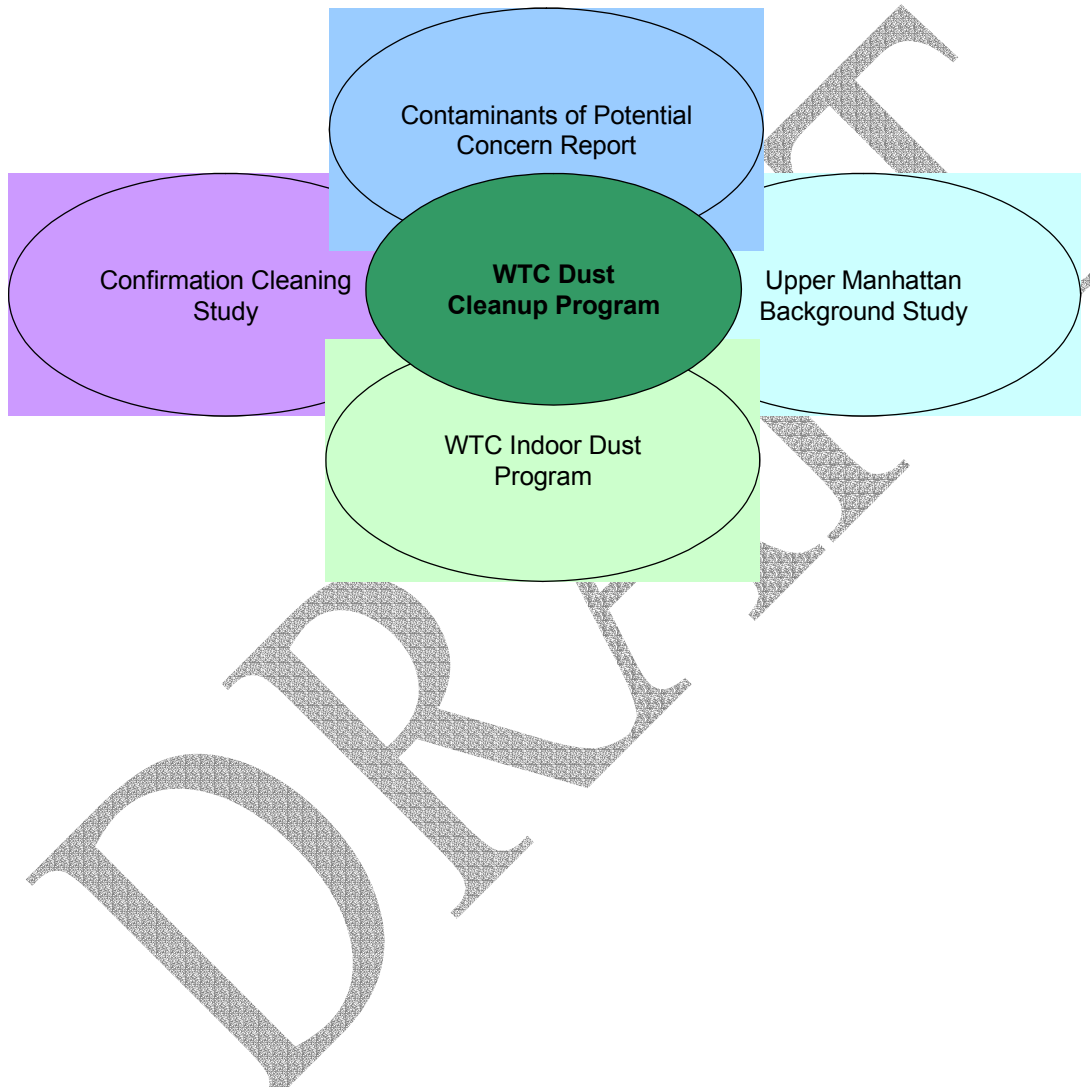


Figure 1-2. Illustration of the four components that comprised the WTC Dust Cleanup Program.

program residents were given the option of requesting either cleaning followed by sampling, or sampling alone. Pursuant to interagency agreements under the Stafford Act, FEMA provided funds to the city, which used its emergency contracting authority to enter into contracts for a hotline contractor to register residents for the indoor dust cleaning program, and with certified asbestos cleanup contractors to professionally clean apartments, as well as with Project Monitors to oversee the cleaning contractors and conduct air monitoring. The actual cleaning and monitoring was carried out by NYCDEP contractors, under the direction and oversight of EPA, in coordination with the city. The samples collected by the NYCDEP contractors were analyzed by EPA contractors.

EPA evaluated the information and data that were gathered in the Confirmation Study (EPA, 2003a) and the Background Study (EPA, 2003b), as well as the results of a peer review of a draft technical document on World Trade Center Contaminants of Potential Concern (EPA, 2003c), as the residential cleaning and monitoring activities proceeded. This document provided the health-based benchmarks for indoor air and settled dust. The data from the Confirmation and Background studies, and the COPC benchmarks, were used to determine whether any program adjustments or modifications were needed. This approach of conducting studies and cleanups in parallel was necessary because of the scientific complexities of dealing with indoor environments and the need for timely response to the potential threat to public health and welfare. For the indoor environment in NYC, EPA had limited indoor sampling protocols, health benchmarks, background data for urban areas (especially Manhattan), correlations of dust to air exposures, etc. This degree of scientific uncertainty made defining a cleanup program very difficult. Cleanup methods that are effective for asbestos and fibrous materials cleanup were employed; these methods were expected to be effective for any other WTC particulate matter that might pose health concerns. Sampling was performed for airborne asbestos in every residence EPA was asked to clean or test, and samples for metals and dioxin were collected from a subset of residences. This provided additional information on the contaminants of potential concern. If the results from the studies indicated the need to modify the cleanup approach, EPA did so. Again, the cleanup efforts and study efforts were performed concurrently by EPA to complete the cleanup of residential spaces as soon as possible. EPA believed this was appropriate given the urgency and scope of the actions needed to help restore Lower Manhattan to pre-9/11 conditions. In developing the Indoor Air Residential Assistance Program-WTC Dust Cleanup, EPA relied on the existing data, the intergovernmental collaboration process, and discussions with scientific, technical, and medical professionals and concerned community members.

The Indoor Air Residential Assistance Program- WTC Dust Cleanup responded to a disaster involving a release that was most certainly not typical, not only because of the terrorist act that led to the release but also because of the unique challenges posed by the presence and potential presence of WTC dust in thousands of Lower Manhattan apartments. When the WTC collapse occurred, there was a release of

asbestos, a hazardous substance, to the environment. The debris and pulverized dust from the collapse affected many structures in Lower Manhattan to varying degrees. This release was documented by bulk dust sampling done by EPA; approximately 35% of bulk dust samples outdoors contained greater than 1 % asbestos, which is a regulatory definition of asbestos-containing material (ACM) under federal, state and local statutes.

Limited investigation of residential indoor environments was conducted in the weeks and months after the WTC collapsed. Two notable studies were the Agency for Toxic Substances and Disease Registry (ATSDR)/ New York City Department of Health and Mental Hygiene (NYCDOHMH) Study, "Final Report of the Public Health Investigation to Assess Potential Exposures to Airborne and Settled Surface Dust in Residential Areas of Lower Manhattan" (ATSDR/NYCDHMH, 2002) and the Ground Zero Taskforce Report, "Characterization of Particulate Found In Apartments After Destruction of the World Trade Center" (Ground Zero Taskforce, 2001). The ATSDR/NYCDHMH Study (2002) was larger (30 study buildings and 4 background [i.e., comparison] buildings) and included both re-occupied and unoccupied apartments. Sampling took place from November 4 through December 11, 2001. The report was released in September 2002; after the EPA indoor air cleanup program was underway. This study showed that total fiber counts of air samples taken in Lower Manhattan were similar to the comparison areas above 59th Street sampled during this investigation. The six Lower Manhattan areas that had elevated total fiber counts were re-examined by transmission electron microscopy (TEM) and scanning electron microscopy (SEM). The TEM and SEM results indicated that neither asbestos nor synthetic vitreous fibers (SVF) contributed to the elevated fiber counts. However, low levels of asbestos were found in some settled surface dust, primarily below Chambers Street. Many of the Lower Manhattan locations sampled had been previously cleaned prior to this investigation. No asbestos was detected in the comparison indoor dust samples taken north of 59th Street. The Ground Zero Taskforce Report (2001) was limited to three apartments that were still undisturbed when sampled on 9/18/01. Samples demonstrated significantly elevated levels of asbestos in the settled dust.

The ACM was deposited in a very variable manner, that is, samples of bulk dust/debris, taken virtually adjacent to each other, had differing levels of asbestos. EPA believes that the dust materials that reached the interiors of structures were likewise variable in its deposition. In addition, some of the material may have contained asbestos at levels of concern for long-term risk, even though it may not have exceeded 1% ACM. Given that there are over 20,000 residential units in Lower Manhattan, specifically identifying which of them were affected by amounts of dust potentially causing long-term health effects would have been time- and resource-intensive. In addition, making risk or exposure assessments in indoor environments is very complex. The age, building materials, house keeping practices, past and current

usage of the space may all impact exposure. The variability of the WTC debris/dust material and the manner in which it affected building interiors adds another layer of complication.

In deciding upon a cleanup program for Lower Manhattan residences EPA considered the following:

- the complexity of sampling dust material for quantities of hazardous substances and the lack of scientific consensus on how to do so;
- the absence of standards that have broad scientific support which relate airborne exposure routes to dust containing hazardous substances; and
- the absence of health- or risk-based standards for dust.

In addition, EPA had to consider how to gauge the residual impacts of cleanups already undertaken by residents who returned to their homes. All of the above have substantial uncertainty or controversy surrounding them.

Federal, state, and city health and medical professionals supported a program that addressed the need for cleanup assurances without the time, expense, and uncertainties associated with a location-specific sampling and risk assessment approach. EPA also consulted with environmental health and science experts in the academic and research sector on the cleanup approach described above. Though there were many questions and a desire for more data collection, they generally acknowledged that a broad-based cleanup program was an appropriate response.

For these reasons, and in consultation with FEMA, New York City, and New York State, EPA determined that rather than taking a risk-based approach to each residential unit or building, cleanup would be performed in any Lower Manhattan apartment based on residents' request.

The attack on and collapse of the WTC was a truly unprecedented event, far different from every other federally declared disaster. As such, EPA believe it warranted a unique response that supplemented FEMA relocation and cleanup assistance programs, was biased towards immediate action to protect the health and safety of the residents of Lower Manhattan, was consistent with federal disaster plan guidelines, and adhered to the applicable and appropriate provisions of the NCP.

Therefore, in response to the WTC collapse, EPA set in motion a program that moved its components (which might otherwise be implemented sequentially) along parallel tracks for the purpose of initiating residential cleanups as soon as possible. These components included: development of health-based benchmarks for indoor air and settled dust (EPA, 2003c); a site-specific characterization of background (EPA, 2003b); and, a study to assess the effectiveness of cleaning methods (EPA, 2003a). Each of these components informed the most important part of the program - the timely cleanup of residential

dwellings. In developing the WTC Dust Cleanup Program EPA relied on existing data, the intergovernmental collaboration process, and discussions with scientific, technical and medical professionals and concerned community members. The concurrent program components, which are schematically illustrated in Figure 1-2 were designed in such a way that adjustments and modifications to the Indoor Dust Program could be implemented based on information, as it became available, from these other initiatives. The material that follows provides a summary of efforts to develop health-based benchmarks, characterize background, and assess the efficacy of cleaning methods, (detailed reports on these efforts have already been issued and are available on the EPA website <http://www.epa.gov/wtc/>); and a detailed analysis of the results of the WTC Dust cleanup Program.

2.0 WTC Dust Cleanup Program Components

As noted in the Introduction of this report, a number of initiatives were undertaken concurrently to expedite the cleanup of residences in Lower Manhattan; they are described below.

Contaminants of Potential Concern Report (COPC)

The first component was an evaluation, conducted by a multi-agency task force headed by EPA, to evaluate indoor environments for the presence of contaminants that might pose long-term health risks to local residents (EPA, 2003c). As part of this evaluation, a task force sub-committee was established (COPC Committee) to identify contaminants of potential concern (COPC) that are likely associated with the WTC disaster and establish health-based benchmarks for those contaminants in support of planned residential cleanup efforts in Lower Manhattan. A systematic risk-based approach was used to select COPC. The goal was to identify those contaminants most likely to be present within indoor environments at levels of health concern. The following chemicals were identified as COPC: Dioxin, PAHs, Lead, Asbestos, Fibrous Glass, and Crystalline Silica.

Health-based benchmarks were developed to be protective of long-term habitability of residential dwellings. A hierarchical approach was employed for developing benchmark values, including relevant and appropriate environmental standards/regulations (HUD standard for lead in indoor dust); calculation of health-based benchmarks employing conventional environmental risk assessment paradigms and guidance (for asbestos, dioxin and PAHs); and adaptation of occupational standards with additional safety factors (fibrous glass and crystalline silica).

Confirmation Cleaning Study

The second component was an effort to confirm that the cleaning methods recommended to the public were effective in reducing contaminants from dust generated from the WTC collapse and recovery efforts (EPA, 2003a). EPA, with support from FEMA and New York City, studied cleaning methods in a heavily contaminated building on Liberty Street, just south of the WTC site. The cleaning confirmation study examined various cleaning and vacuuming methods that were likely to be used by or were recommended to residents and professional cleaning companies to clean dust and debris from residential living areas in the aftermath of the attacks.

EPA contractors cleaned homes and a few commercial spaces in the building that contained a complex mixture of contaminants, including construction debris and fire-related compounds.

Eleven cleaning methods were selected and assigned to the residential units within the building according to the levels of observed dust. Each cleaning method was tested in units with significant and minimal levels of dust. The following cleaning methods were used:

- Residential quality upright vacuums and shop vacuums
- Residential quality upright vacuums with the addition of an air filtration device (AFD)
- HEPA-filtered upright and shop vacuums
- HEPA-filtered upright and shop vacuums with the addition of an AFD
- Industrial quality HEPA-filtered vacuums
- Industrial quality HEPA-filtered vacuums with the addition of an AFD
- Wet wiping of all horizontal and/or vertical surfaces with soap and water
- Carpet cleaning
- Standard cleaning procedures used by professional duct cleaning companies for the cleaning of air conditioning (A/C) systems, ducts and related equipment
- Use of water only for wet wipe of horizontal and/or vertical surfaces
- Scope A cleaning procedures developed by EPA and New York City for the cleaning of residential units in Lower Manhattan (EPA, 2003a)

Results were compared to health-based benchmarks for COPCs identified above to determine if the cleaning was successful. A summary of the significant conclusions of the study is provided below. These include observations about the extent of WTC-related contamination within the building and the effectiveness of the cleaning methods tested in the study.

- The observation of WTC dust is a reasonable indicator that WTC contaminants may be present and that the amount of WTC dust correlates with the level of contamination.
- Concentrations of some contaminants in the WTC dust were elevated above health-based benchmarks.
- The use of a standard cleaning method of vacuuming and wet wiping significantly reduced levels of WTC-related contamination with each cleaning event and was successful in reducing concentrations to levels below health based benchmarks.
- In some cases, multiple cleaning sessions (2 or 3) were necessary to reduce contamination. The methods were highly effective in reducing all COPC below health-based benchmarks.

- Asbestos in air is a reasonable indicator of whether additional cleaning is needed. Based on the compounds and testing methods chosen, the data suggests that using asbestos air samples as an indicator for additional cleaning is the most sensitive of the testing methods, as it resulted in the largest percentage of additional cleanings.
- Standard HVAC cleaning methods reduced the concentrations of WTC contaminants in HVAC systems.

WTC USEPA Background Study

The third component of the USEPA's WTC response was a background study (EPA, 2003b) to determine concentrations of building-related materials and combustion byproducts in residential dwelling.

A background study was initiated because limited information was available in the literature for the analytes that were identified in WTC-related dust. Characterization and evaluation of the degree of impact to the indoor environments required knowledge regarding pre-attack concentrations of the potential indoor contaminants. Although the COPC identified in WTC-related dust have been used extensively in building construction or studied as environmental contaminants, there is limited information available that reports background concentrations of these compounds in urban residential indoor environments.

The objective of the background study was to determine the indoor concentrations of building-related materials and materials found in fire-related combustion byproducts, including asbestos, synthetic vitreous fiber (SVF), fibrous glass, crystalline silica (as alpha-quartz), calcite, gypsum, dioxin, and polycyclic aromatic hydrocarbons (PAHs). The results from the background study were to provide a basis upon which to make risk management decisions if the health-based benchmarks could not be realistically achieved. The estimated background values that were derived from the background study were not used because the health-based benchmarks were consistently achieved.

Volunteers residing in Upper Manhattan locations that were minimally impacted by the WTC collapse were recruited for the study. The outer boundary of the affected area was determined from a preliminary dispersal and dilution model using meteorological data on September 11, 2001 (EPA, 2001) and shortly thereafter. Computer modeling results showed that Upper Manhattan locations north of 78th Street, approximately eight kilometers or five miles from the WTC site, would be minimally affected by WTC fallout dust. The computer model predicted that the concentration of fallout particulate matter for areas north of 78th Street would be from 1,000 – 10,000 times less than that at the WTC site (Figures 2-1 and

2-2). Air and settled dust samples were collected from 25 residential units and 9 common areas within 14 buildings. The sampled buildings were approximately 8 – 19 kilometers (5 – 12 miles) northeast of the WTC site. When possible, samples were collected from two residential units and from one common area, such as the lobby, hallway, stairwell, or shared laundry facility in each building. The comparison of the results from the background study to the data from the WTC site did not include formal tests to determine if the concentrations were statistically significant due to the disparity in the number of samples that were collected from each building, and the large number of samples that were collected in each study with results below detection limits (i.e., high rate of *non-detects*).

Evaluation of the data collected from the WTC USEPA Background Study was able to: provide estimates of baseline levels or background concentrations of compounds that were identified as COPCs related to the World Trade Center collapse; show that the estimated background concentrations were consistent with other background studies and historical data, when comparison data were available; and, provide a source of data to help address data gaps in the scientific literature on background concentrations of building-related materials.

Overview of the WTC Dust Cleanup Program

Registration for the WTC Dust Cleanup Program was open from June 05 through December 28, 2002. EPA conducted a public outreach initiative to inform residents about the Program. Components of this initiative included: distribution of pamphlets at residential buildings, subway stations and local businesses; meetings with community groups; operation of a registration hotline; establishment of a website for on-line registration; mailings; and, newspaper advertisements.

The WTC Dust Cleanup Program was open to all residents living below Canal Street. Upon signing up, residents had a choice of receiving a cleaning with confirmatory testing, or, in the event the residence was already professionally cleaned and/or not significantly impacted by the WTC collapse, testing only. A description of the cleaning protocol is summarized below.

Cleanup work was conducted by contractors and workers (the Cleanup Contractor) certified by New York State and New York City. Separate, third-party contractors, also licensed by New York State, oversaw the cleanup work and conducted all testing (the Project Monitor). Further direct oversight was provided by EPA personnel. All personnel involved in this program carried appropriate photo identification.

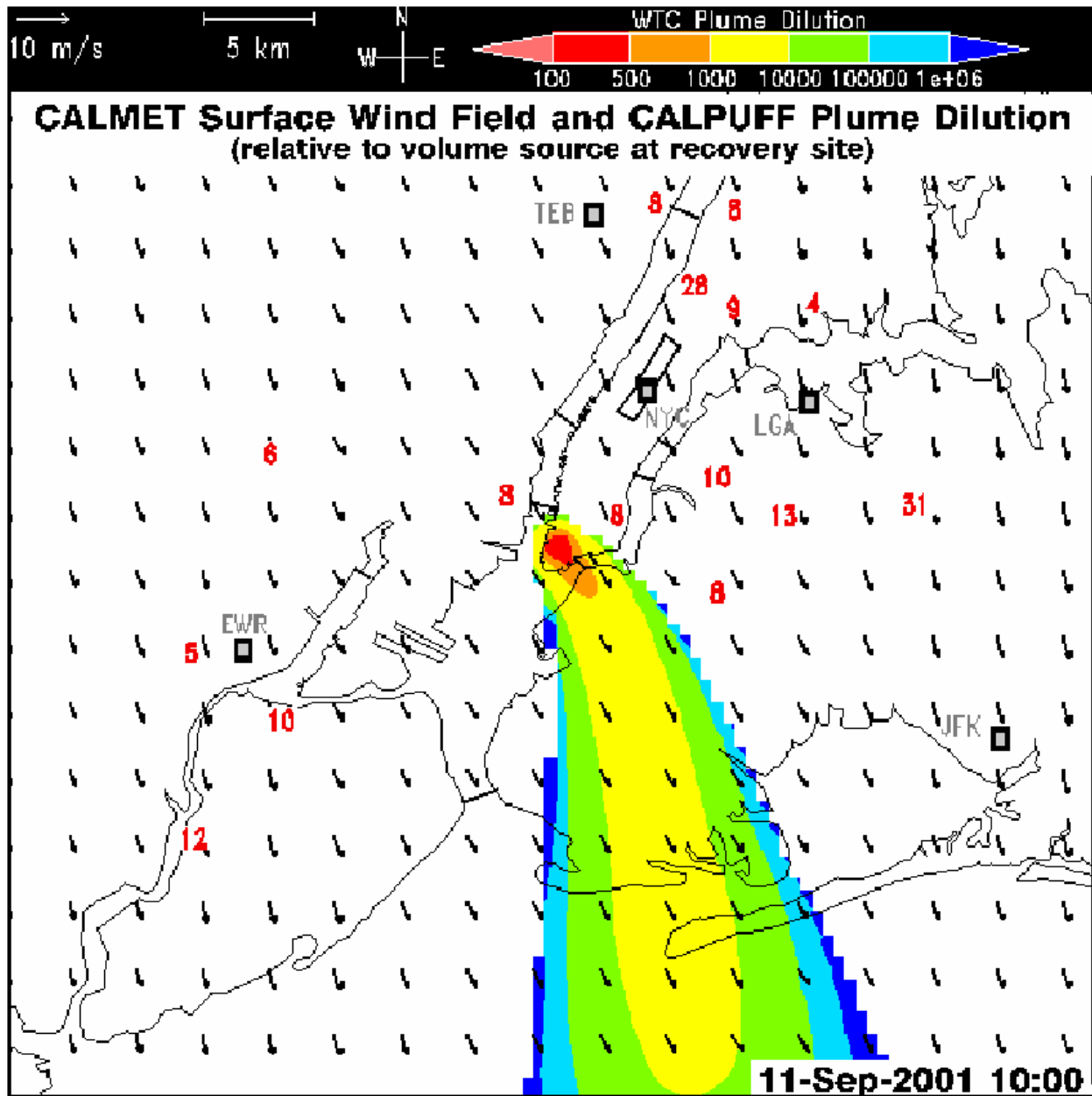


Figure 2-1. Simulation of WTC plume on the morning of the attack. National Oceanic and Atmospheric Administration meteorological stations are indicated as: Newark (EWR), Teterboro (TEB), LaGuardia Airport (LGA), Central Park (NYC) and John F. Kennedy Airport (JFK). Numbers in red are the hourly average concentration of particulate matter $\leq 2.5 \mu\text{m}$ in size in $\mu\text{g}/\text{m}^3$. Plume direction is towards the south-southeast and dilution of the plume varies from less than 500 to approximately 1,000,000.

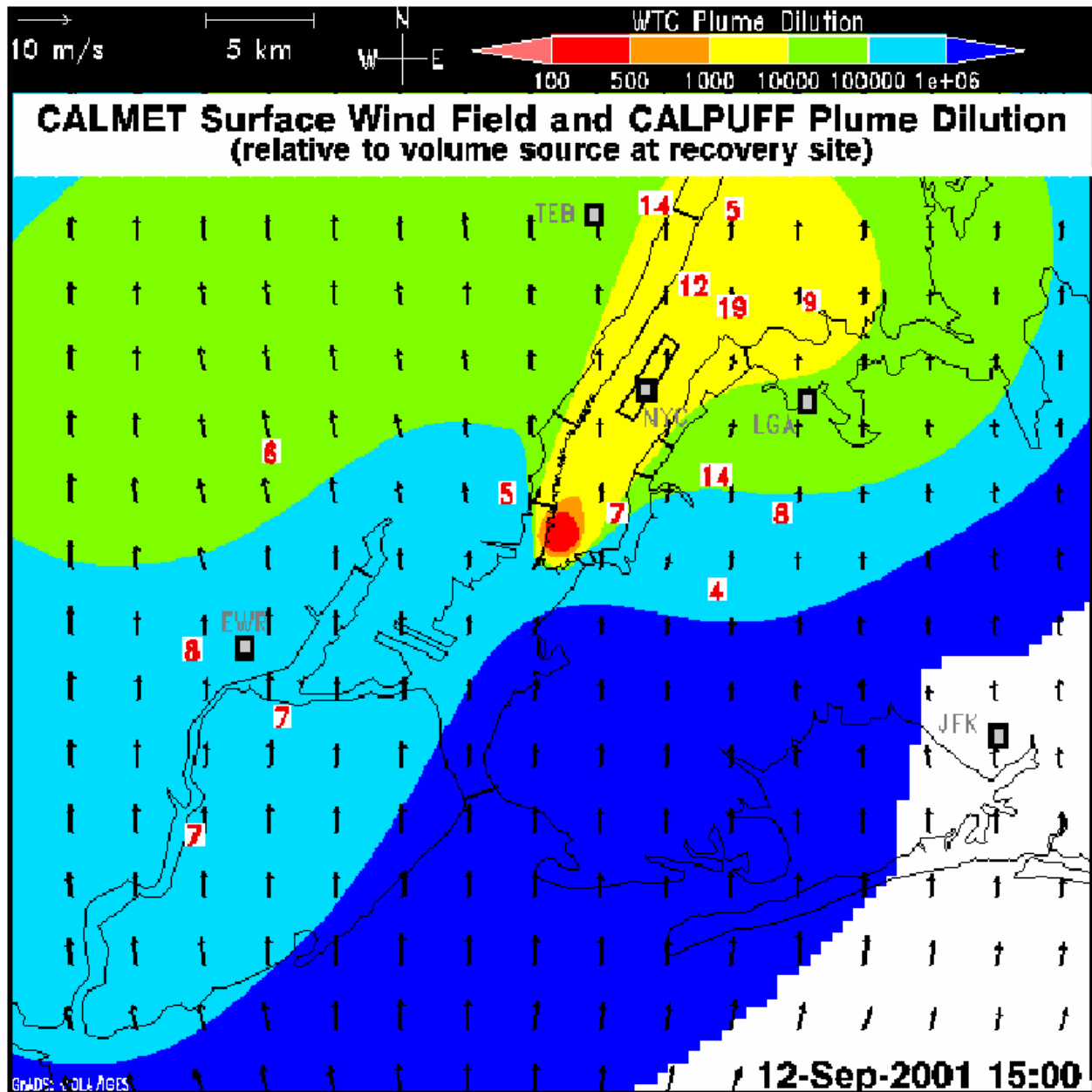


Figure 2-2. Simulation of WTC plume in the afternoon the day after the attack. National Oceanic and Atmospheric Administration meteorological stations are indicated as: Newark (EWR), Teterboro (TEB), LaGuardia Airport (LGA), Central Park (NYC) and John F. Kennedy Airport (JFK). Numbers in red are the hourly average concentration of particulate matter $\leq 2.5 \mu\text{m}$ in size in $\mu\text{g}/\text{m}^3$. Plume direction is primarily towards the northeast.

The Project Monitor contacted residents requesting assistance to confirm and schedule cleanup and testing. The Project Monitor had access to a translation service to assist with the process for those whose primary language is not English. There were three phases to the actual work: 1) Pre-cleaning inspection; 2) Cleaning; and 3) Testing.

Owners and managers of residential buildings and coop boards could request to have their building's common areas cleaned and HVAC system evaluated and cleaned, if necessary. After receiving the request, common areas such as the building lobby, hallways, stairways and elevator interiors would be cleaned. Other common areas, including laundry rooms, utility rooms, compactor rooms, and elevator shafts were evaluated and cleaned as needed.

During a pre-cleaning inspection for an individual residence, the Project Monitor met with the occupant(s) to assess conditions, discuss procedures and testing options, determine any special concerns or needs, and answer questions. The Project Monitor obtained written access and authorization, and scheduled the cleaning work. Residents were given information about preparing for cleaning including the handling of valuable personal items, the presence of pets, etc. The Project Monitor discussed the level of cleanup required (see below) and resident's options for post-cleanup testing.

Damage to a building as a result of the WTC collapse may have resulted in the growth of mold in apartments. As part of the Cleaning Program, the Project Monitor contacted the NYCDOHMH if mold was observed in a residence or residential building. The NYCDOHMH then contacted the building owner to provide recommendations on how to address the affected areas. Further information regarding mold can be found in the NYCDOHMH fact sheet entitled "Facts About Mold" (NYCDOHMH, 1994). (<http://www.ci.nyc.ny.us/html/doh/html/epi/epimold.html>)

If the Project Monitor identified the presence of potential friable asbestos type insulation in areas requested to be cleaned, it was reported to NYCDEP for evaluation and appropriate follow up action. Likewise, if the Project Monitor identified potential peeling, flaking or chalking paint, the NYCDOHMH was notified for evaluation and appropriate follow up action.

Cleaning Scope

Following the assessment, the Project Monitor determined the appropriate cleanup approach. Most residences were addressed under EPA's "Scope A" cleanup. Residences (typically unoccupied) where there was still significant amounts of WTC dust and/or debris were dealt with under EPA's "Scope B" cleanup which adds precautions to require further worker protection and techniques to minimize

spreading of possible contamination while removing the dust/debris. Areas where localized accumulations of WTC dust were found in a residence which otherwise had minimal dust (i.e., between windows, inside air conditioners), were addressed under a Scope B cleanup, wherein the areas containing the dust were isolated from the remainder of the residence prior to removal. Residents (or their representatives) may have been present (but did not have to be) during Scope A cleanings. Residents were not allowed to be present during Scope B cleanings, unless the Scope B cleanup applied to only parts of the residence. In most cases, cleaning operations took no more than two days.

In a Scope A cleanup, all horizontal hard surfaces, including floors, ceilings, ledges, trims, furnishings, appliances, equipment, etc., were HEPA vacuumed and wet wiped. Vertical and soft surfaces were HEPA vacuumed two times. Dry sweeping was prohibited. A detailed description of the minimum cleaning requirements is listed below (field experience may have resulted in the modification of these procedures):

- Terraces, balconies, exterior window sills, window wells and window guards that are accessible from the interior of the dwelling, will be cleaned.
- Interior windows, screens, window sills and window guards will be cleaned.
- Vacuuming will begin with the ceiling, continue down the walls and include the floor.
- Impermeable walls and floors will be wet wiped using disposable wipes, after consultation with and approval by owner. Wet wiping will not be conducted if it is determined that it would cause damage to the surface.
- Curtains, fabric window treatments, upholstery and other materials that cannot be cleaned by wet wiping shall be HEPA vacuumed two times. Fabric covered furniture will be vacuumed using a stiff brush attachment.
- Carpets will be cleaned with a water extraction cleaner equipped with a motorized agitator brush. Water extraction cleaning will not be conducted if it is determined that it would cause damage to the carpet.
- Paperwork and books will be HEPA vacuumed.
- Electrical outlets will be vacuumed.
- Window air conditioners will be vacuumed then removed from their position and vacuumed internally. Filters will be HEPA vacuumed and reinstalled. Air conditioners will be reinstalled after cleaning.
- Intake/discharge registers of HVAC systems (if present) will be removed/cleaned. The first foot of duct work will also be vacuumed, then the register will be reinstalled and covered with plastic.
- Appliances such as refrigerators and stoves will be cleaned and moved. The floor footprint of the appliances will be cleaned and the appliance will be reinstalled in its original position.
- Refrigerator cooling tubes will be brushed and vacuumed.
- Stove exhaust fan filters will be cleaned.
- The first foot of all exhaust duct work (including stove, dryer and bathroom vents) will be vacuumed. Exhaust fans will be vacuumed and wiped.

- Closet floors will be vacuumed.
- Solid objects (electrical equipment, exercise equipment, etc.) will be wet wiped, moved to allow cleaning of the underlying surface and will be returned to their original location.
- Dishwasher toe plates will be removed and the floor beneath the appliance will be cleaned.
- Baseboard heaters will be cleaned. Protective covers on finned radiant heaters and baseboard heaters will be removed to expose heat elements. Fins are to be brushed and vacuumed to remove dust.
- All cleaning equipment will be vacuumed and/or wet wiped for use on the residence.

In a Scope B cleanup, the areas containing dust and/or debris were sealed off and exhaust fans equipped with HEPA filters were used to lower the air pressure within the sealed off area so that no dust escaped. Dust and debris were bagged and sealed for removal. Workers wore protective gear and residents were not allowed within the sealed off area. Scope B work could be applied to an entire residence or to portions of a residence where remnants of bulk dust were discovered.

Testing Protocol

Sampling was conducted no later than 24 hours after clean-up was completed. For “test only” apartments sampling was conducted in the absence of a cleaning event. Air samples, that were analyzed for both asbestos (separate counts for long, i.e., >5 um length, versus total fibers) and non-asbestos fibers, were obtained from all residences. Generally, one sample was obtained from each room in an apartment or from contiguous areas in common spaces. A subset of “clean and test” (approximately 200) and “test only” (approximately 50) apartments received wipe sampling for 23 metals plus dioxin. A description of the testing (sampling and analysis) protocol is summarized below.

When cleaning was completed, the Project Monitor did a visual inspection. If dust was observed, the residence was re-cleaned as necessary. Once the visual inspection found the residence to be dust free, final air sampling was authorized.

This final testing phase took approximately eight hours and was completed within one day (24 hours) of the completion of cleanup work. Residents had a choice between two forms of airborne asbestos testing, modified-aggressive and aggressive. Modified-aggressive testing simulates the normal air movement in a room where a fan or air conditioner is running. In aggressive testing, a one-horsepower leaf blower was used to blast air into all corners of the residence before testing was begun. From that point on, the two tests are identical. Any air conditioners were turned on and 20-inch fans (one per 10,000 cubic feet of room space) were run at low speeds for the duration of the test. Depending on the number of rooms in a residence, from three to five air samplers were located in the residence and run for approximately eight

hours. These samplers draw in a measured volume of room air and collect dust from the air on a filter. The collected dust is then examined in a laboratory for asbestos using transmission electron microscopy (TEM). Additional analysis by phase contrast microscopy (PCM) was conducted to obtain a count of non-asbestos fibrous material.

Residents may have occupied their home during modified-aggressive testing but were cautioned to be prepared for noise and disruption. Occupants with known allergies, asthma or other health concerns were advised to consider contacting their health care provider to determine whether it was advisable to be present while cleaning and/or testing was underway. Residents were required to relocate during, and for 48 hours after, aggressive testing. The Red Cross agreed to provide financial assistance to defray costs for relocation expenses. Information from the Red Cross was provided as needed. Occupants were required to remove or secure objects, including pictures and artwork that could be blown over or otherwise damaged.

The Project Monitor conducted a post-cleaning inspection of the apartment with the resident at the completion of modified-aggressive sampling, or upon re-entry after aggressive sampling. During this inspection the project monitor and the resident determined whether cleaning/monitoring activities were completed and whether any property damage or loss had occurred. The resident then signed a Project Completion Form.

At a limited number of “clean and test” residences (approximately 200), the Project Monitor conducted pre- and post-cleanup wipe sampling for dioxin, mercury and metals. Approximately 50 “test only” residences received a single round of wipe sampling for dioxin, mercury and metals. Generally, wipe samples were obtained from three discrete surfaces within an apartment. Results of this sampling, along with interpretation through a comparison with health-based benchmarks, were shared with occupants of the residences.

EPA notified residents and owners of the results of the post-cleanup airborne asbestos testing. Notification letters included an interpretation of the TEM results for long (>5 um) asbestos fibers through comparison with EPA’s cleanup criteria (see below). Additional information was provided on the results of total asbestos fibers (>0.5 um) by TEM and total non-asbestos fibers by PCM analysis. Residence-specific test results were not made public. Residences were re-cleaned and re-tested if any post-cleanup samples registered levels of asbestos in excess of EPA’s cleanup criteria. For “test only” apartments, residents were eligible for cleaning if any airborne asbestos samples exceeded EPA’s cleanup criteria. A technical discussion of asbestos air sampling and metals/dioxin wipe sampling can be accessed at www.epa.gov/wtc (See EPA’s WTC Residential Confirmation Cleaning Study; EPA, 2003a).

Interpretation of test results

Clearance criteria were developed for evaluating airborne asbestos sampling results. A health-based value of 0.0009 f/cc was established based on TEM analysis of phase contrast microscopy equivalent (PCMe) fibers. The TEM analysis protocol was adapted from the Asbestos Hazard Emergency Response act (AHERA) and modified to count only asbestos fibers greater than 5 microns in length, with an aspect ratio greater than 5:1, and no minimum width requirement. The basis for the clearance criteria of 0.0009 f/cc (PCMe) is detailed in the COPC Report.

As previously stated, residences were re-cleaned and re-tested if the post-cleanup testing found levels of asbestos in excess of the cleanup criteria of 0.0009 f/cc (PCMe). There were a number of outcomes that resulted in inconclusive results. Filter overload (defined as dust deposition obscuring more than 10-25% of the filter), which compromises the ability to accurately count asbestos fibers, was the most common cause of inconclusive results. Other causes of inconclusive results included blown and/or damaged filters. Apartments with overloaded and/or blown/damaged filters were re-cleaned and re-tested. In addition, sampling results for total asbestos fibers greater than 0.5 microns in length (as per AHERA counting rules), and total non-asbestos fibers by PCM analysis were evaluated on a case-by-case basis.

Wipe Sampling

The wipe samples taken as part of the Dust Cleanup Program supplemented the findings of the WTC Confirmation Cleaning Study by providing additional information obtained under actual field conditions. While this single sampling event, conducted approximately 18 months after the release, could not reconstruct the collective exposure incurred since 9/11, it could serve to put into context the existing contaminant levels in settled dust by comparing the results of the sampling to health-based benchmarks (see EPA, 2003a, Appendix Z, Table Z.3) developed for the WTC Clean-up Program.

Wipe samples were collected and analyzed in accordance with the procedures and methods presented in the Quality Assurance Project Plan (QAPP). Procedures for the collection of wipe samples are detailed in Appendix F of the QAPP (EPA, 2003a). Samples were collected and analyzed for 22 metals, mercury and dioxin (EPA, 2003a, Appendix Z, Table Z.3). Of these, dioxin and lead were identified as COPCs that are likely associated with the WTC disaster. A summary of the wipe sample results is presented in Appendix Z. Detailed results for lead and dioxin are provided in Section 3.

3.0 WTC Dust Clean-up Program

Data analyzed in this report were extracted from the Residential database on September 10, 2003. A copy of the data set, with data necessary to protect the privacy of individual participants in the program redacted, is available from the EPA Region 2 Records Center. Appendix B contains a detailed discussion of the results presented in this section.

Overall, the data indicate a low rate of exceedance of the health-based benchmarks that were established for the WTC cleanup effort. The exceedance rates for airborne asbestos, and the exceedance rates for dust loading for the 21 metals other than lead, were less than 0.5 % on a sample-basis. The exceedance rate for dust lead loading decreased from approximately 14% before cleanup, to 3% after cleanup, on a sample-basis. The exceedance rate for dust dioxin loading was less than 1% before and after cleanup.

3.1 DATA SUMMARY

3.1.1 Summary of TEM (PCMe) data

Table 3-1 summarizes the sample results for asbestos. The data described in this section and Section 3.1.2 are results for asbestos phase contrast microscopy equivalent (PCMe) concentrations measured by transmission electron microscopy (TEM). A total of 28,702 sample results were available for asbestos by PCMe; 22,497 from residential units, and 6,205 from common areas within residential buildings (e.g., hallways, laundry rooms). Samples for PCMe analysis were collected from residential units that were tested only, as well as from residential units and common areas that were cleaned and tested. Results by PCMe were compared to the health-based benchmark of 0.0009 f/cc (fibers/cubic centimeter) to determine the status of the residential units/common areas.

The asbestos clearance criteria for the WTC Indoor Air Clean-up Program were based on long (i.e., $\geq 5 \mu\text{m}$) fiber counts. The use of a minimum fiber length of 5 μm for carcinogenic activity represents current scientific consensus and reflects the criteria in EPA's Integrated Risk Information System (IRIS) toxicity data base for attributing carcinogenic potency.

Table 3-1. Summary of Available Asbestos PCMe Results

Summary of residential airborne asbestos data. The data represent phase contrast microscopy equivalent (PCMe) concentrations measured by transmission electron microscopy (TEM). The health-based benchmark of 0.0009 fibers/cubic centimeter was exceeded in a very small fraction of the samples. Occupants of residences with one or more exceedance for PCMe were offered recleaning.

Sample Type	Residential Samples	Common Area Samples
Samples collected	22,497	6,205
Number of samples >0.0009 ^a (exceeds)	102	21
Percent exceeds	0.45%	0.34%
Maximum concentration	0.0204	0.0042
Minimum concentration	Not detected ^b	Not detected

^aThe health-based benchmark for asbestos is 0.0009 fibers/cubic centimeters.

^bDetection limit ranged from 0.0004 to 0.0005 fibers/cubic centimeters.

Phase Contrast Microscopy equivalence is a process to identify asbestos fibers by TEM analysis that would also be visible by PCM. The optical resolution of the phase contrast microscope is approximately 5 microns in length and 0.25 microns in width for fiber analysis. Historically, most of the occupational studies available (and reviewed by IRIS) to estimate the cancer potency of asbestos, employed PCM analysis. Therefore, in cases where TEM is used for asbestos analysis, fiber counts need to be adjusted to PCMe.

The asbestos counting rules employed for the WTC Indoor Clean-up Program were designed to record PCMe fibers. Thus, TEM analyses were performed and fibers were then counted following AHERA (Asbestos Hazard Emergency Response Act) counting rules. Fibers $\geq 5 \mu\text{m}$ (AHERA also stipulates a minimum 5:1 aspect ratio) were distinguished from total (i.e., $>0.5 \mu\text{m}$) fiber counts, although total fiber counts were also recorded. To maximize analytical capacity for a large sampling event, no minimum width requirement was employed. This may have resulted in a modest over counting bias by not eliminating extremely thin fibers (i.e., $<0.25 \mu\text{m}$) from the count. However, the potential bias attributed to this counting procedure would be protective of human health. Modification was made to AHERA (by obtaining larger samples volumes) in order to achieve the lower detection limits required by the use of a risk-based clearance criteria.

3.1.2 Summary of TEM data.

Table 3-2 lists the types of asbestos that were detected by TEM in the airborne asbestos samples from residences and common areas. Asbestos was detected in approximately 4% of the available TEM samples. Chrysotile asbestos was detected in approximately 92% of the samples included in this subset of the data; amosite was detected in approximately 3%. Other forms of asbestos that were detected included actinolite, anthophyllite, tremolite, and crocidolite.

3.1.3 Summary of Dust Wipe data

Summary of Dust Lead Wipe Data

The database contained 1,540 wipe samples for dust lead loading that were collected from 263 residences, located in 157 buildings. Summary statistics for the data are provided in Table 3-3a. Samples that were below the detection limit of $1.86 \mu\text{g}/\text{ft}^2$ were set equal to the detection limit. Review of existing environmental standards/regulations identified an applicable and relevant standard to set a health-based benchmark for lead in interior dust. The Residential Lead-Based Paint Hazard Reduction Act (Title X) Final Rule (40 CFR, Part 745, 1/5/01) established uniform national standards for lead in interior dust.

Table 3-2. Number of Samples of Residential Airborne Asbestos Analyzed by Transmission Electron Microscopy (TEM) and By Asbestos Type Detected

For samples where asbestos was detected; chrysotile was encountered in approximately 92% of the residential samples, and in 91% of the samples collected from common areas. The next most frequently identified type of asbestos was amosite (3% in residential, 4% in common areas).

Asbestos type	Residential Samples	Common Area Samples
Not detected	21,543	5,926
Actinolite	9	1
Amosite	31	10
Amosite/Chrysotile	3	2
Amosite/Chrysotile/Crocidolite	1	0
Amphibole	1	3
Anthophyllite	6	3
Anthophyllite/Chrysotile	3	1
Chrysotile	878	255
Chrysotile/Actinolite	6	0
Chrysotile Amphibole	0	2
Chrysotile/Tremolite	3	0
Crocidolite	1	0
Gypsum fibers present ^a	7	0
Tremolite	5	2
Total	22,497	6,205

^aNon asbestos fibers.

Table 3-3. Statistics for All Lead Wipe Data Combined ($\mu\text{g}/\text{ft}^2$)

This table provides summary statistics for residential dust lead loading data that was collected from residences that were cleaned and tested (both before and after cleanup), and tested only.	
Apartments sampled ^a	263
Buildings sampled	157
Number of samples	1540
Nondetects	264 (17.1%)
Exceedances @ 25 $\mu\text{g}/\text{ft}^2$ ^a	136 (8.8%)
Exceedances @ 40 $\mu\text{g}/\text{ft}^2$ ^b	95 (6.2%)

^aThe database contains matching data (i.e., pre- and post-cleanup data) for 214 apartments, and unmatched data (i.e., only pre-cleanup or only post-cleanup) for 49 apartments, for a total of 263 apartments..

^bExceedance: lead wipe samples that exceeded the health-based benchmark of 25 $\mu\text{g}/\text{ft}^2$

Thus, both EPA and the United States Department of Housing and Urban Development (HUD) have set a dust standard for lead of 40 $\mu\text{g}/\text{ft}^2$ for floors (including carpeted floors), and 250 $\mu\text{g}/\text{ft}^2$ for interior window sills. To support the development of a dust standard, EPA performed an analysis of the Rochester Lead-in-Dust Study (HUD, 1995). At 40 $\mu\text{g}/\text{ft}^2$, a multimedia analysis shows a 5.3% probability that a child's blood lead level would exceed 10 $\mu\text{g}/\text{dL}$. Thus, this standard meets the criteria established by EPA (i.e., 95% probability to be below 10 $\mu\text{g}/\text{dL}$) (EPA, 1994) for managing environmental lead hazards. However, an additional increment of protectiveness was added by setting the health-based benchmark for lead in settled dust at the more stringent HUD screening level of 25 $\mu\text{g}/\text{ft}^2$. Approximately 9% of all lead wipe samples (i.e., *test only* and *clean and test*) were above the HUD screening level of 25 $\mu\text{g}/\text{ft}^2$ (Table 3-3); approximately 14% of the pre-cleanup samples exceeded the HUD screening level, while approximately 3% of the post-cleanup samples exceeded the screening level (Tables 3-4 and 3-5). Approximately 6% of the samples were above the HUD benchmark of 40 $\mu\text{g}/\text{ft}^2$ (Table 3-3).

Summary of Dust Dioxin Wipe Data

The database contained 1,535 wipe samples for dust dioxin loading that were collected from 263 residences, located in 157 buildings. Basic statistics for the data are provided in Table 3-6. The dioxin results were modified using a toxicity equivalency quotient (TEQ), which takes into account the toxicity differences between 17 congener groups. The results are reported in 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) equivalents. The TEQ value reported in the table represents the estimated maximum potential concentration (EMPC). The TEQ EMPC value used data that indicated the presence of a congener above zero ng/m^2 even if all of the QA/QC reporting level criteria were met for that sample. This value represents the highest potential concentration of dioxin that may have been present. At least one of the 17 congeners was detected in 1,136 of the samples; the remaining 399 samples were reported as below the detection limit for each congener. Only 8 of the 1,535 (approximately 0.5%) of the combined samples (i.e., *test only* and *clean and test*; Table 3-6) exceeded the health-based benchmark for residential dust dioxin loading of 2 ng/m^2 (Table 3-6).

Summary of Dust Wipe Data for Other Metals

Data for 21 metals, in addition to lead, were collected. Statistics for the 21 metals (plus lead and dioxin), and the reduction in the average dust loading rates for each, are provided in Table 3-7. The data are grouped into three categories in Table 3-7: samples collected from residences and common areas that were cleaned and tested (*clean and test samples*), samples that were collected from residences that were tested only (*test only samples*), and the combination of these two categories (*all samples*).

Table 3-4 here

Table 3-4. Statistics for Lead Wipe <i>Clean and Test</i> Data.		
<p>The <i>clean and test</i> subset of the data exhibit very high positive skewness and high variability. The raw data and log-transformed pre- and post-cleanup data fail the S-W test for normality (log-transformed data [pre-/post-]: S-W statistic=0.89/0.85, $p<0.0001/p<0.0001$). This table includes two observations that have been treated as outliers in subsequent analyses (see Section 3.4.1 for details). Statistics for the data set, after removal of the two outliers, are provided in Tables 3-7a and A-1a.</p>		
Statistic	Pre-cleanup	Post-cleanup
Apartments sampled	214	214
Buildings sampled	145	145
Number of samples	680	674
Nondetects	101 (14.8%)	140 (20.8%)
Exceedances @ 25 $\mu\text{g}/\text{ft}^2$ ^a	93 (13.7%)	21 (3.1%)
Exceedances @ 40 $\mu\text{g}/\text{ft}^2$ ^b	67 (9.9%)	12 (1.8%)
Minimum	1.86	1.86
Median	7.32	6.38
Mean	35.46	19.03
Maximum	6790	7250
Standard deviation	286.03	279.64
Skewness	20.56	25.77
CV ^c	8.07	14.70
S-W Statistic ^d	0.07	0.03
Prob Normal ^e	<0.0001	<0.0001

^aExceedance: lead wipe samples that exceeded the health-based screening level of 25 $\mu\text{g}/\text{ft}^2$

^bExceedance: lead wipe samples that exceeded the HUD health-based benchmark of 40 $\mu\text{g}/\text{ft}^2$

^cCV=coefficient of variation=standard deviation/mean

^dS-W Statistic: Shapiro-Wilk statistic

^eProb Normal: probability the data are from a normal distribution

Table 3-5. Statistics for Lead Wipe *Clean and Test* Data with Outliers Removed.

The *clean and test* subset of the data exhibit very high positive skewness and high variability. The raw data and log-transformed pre- and post-cleanup data fail the S-W test for normality (log-transformed data [pre-/post-]: S-W statistic 0.90/0.89, $p < 0.0001$ / $p < 0.0001$). This table excludes two observations that have been treated as outliers (see Section 3.4.1 for details).

Statistic	Pre-cleanup	Post-cleanup
Apartments sampled	214	214
Buildings sampled	145	145
Number of samples	679	673
Nondetects	101 (14.9)	140 (20.8)
Exceedances @ 25 $\mu\text{g}/\text{ft}^2$ ^a	92 (13.5)	20 (3.0)
Exceedances @ 40 $\mu\text{g}/\text{ft}^2$ ^b	66 (9.7%)	11 (1.6%)
Minimum	1.86	1.86
Median	7.32	6.37
Mean	25.52	8.28
Maximum	2530	394
Standard deviation	121.00	19.79
Skewness	15.24	13.89
CV ^c	4.74	2.39
S-W Statistic ^d	0.15	0.21
Prob Normal ^e	<0.0001	<0.0001

^aExceedance: lead wipe samples that exceeded the health-based screening level of 25 $\mu\text{g}/\text{ft}^2$

^bExceedance: lead wipe samples that exceeded the HUD health-based benchmark of 40 $\mu\text{g}/\text{ft}^2$

^cCV=coefficient of variation=standard deviation/mean

^dS-W Statistic: Shapiro-Wilk statistic

^eProb Normal: probability the data are from a normal distribution

**Table 3-6. Statistics for All Dioxin (TEQ)
Wipe Data (ng/m²)**

This table provides summary statistics for residential dust dioxin loading data that was collected from residences that were cleaned and tested (both before and after cleanup), and tested only.

Apartments sampled ^a	263
Buildings sampled	157
Number of samples	1535
Nondetects	399 (26.0%)
Exceedances ^b	8 (0.52%)

^aThe database contains matching data (i.e., pre- and post-cleanup data) for 214 apartments, and unmatched data (i.e., only pre-cleanup or only post-cleanup) for 49 apartments, for a total of 263 apartments.

^bExceedance: dioxin wipe samples that exceeded the health-based benchmark of 2 ng/m² TEQ EMPC (ND = 1/2).

Table 3-7. Dust Wipe Sample Data

Table 3-7. Dust Wipe Sample Data								
Total Samples			Matched Pre- and Post-Cleaning Samples			Test Only Samples		
Aluminum	Number	Percentages	Aluminum	Number	Percentages	Aluminum	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	1536	99.5%	Detects	1329	99.5%	Detects	102	99.0%
Nondetects	8	0.5%	Nondetects	7	0.5%	Nondetects	1	1.0%
Nondetects @ 200	7	87.5%	Nondetects @ 200	7	100.0%	Nondetects @ 200	0	0.0%
Nondetects @ 1000	1	12.5%	Nondetects @ 1000	0	0.0%	Nondetects @ 1000	1	100.0%
Max	319000		Max	296000		Max	45500	
Min	ND @ 200		Min	ND @ 200		Min	ND @ 248	
Exceedences	0	0.0%	Exceedences	0	0.0%	Exceedences	0	0.0%
			Avg Pre-Means:	3258.97				
			Avg Post-Means:	1093.05				
			Avg % Reduction:	35.44				
Antimony	Number	Percentages	Antimony	Number	Percentages	Antimony	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	13	0.8%	Detects	7	0.5%	Detects	4	3.9%
Nondetects	1531	99.2%	Nondetects	1329	99.5%	Nondetects	99	96.1%
Nondetects @ 80	1526	99.7%	Nondetects @ 80	1329	100.0%	Nondetects @ 80	94	94.9%
Nondetects @ 400	5	0.3%	Nondetects @ 400	0	0.0%	Nondetects @ 400	5	5.1%
Max	1180		Max	1180		Max	404	
Min	ND @ 80		Min	ND @ 80		Min	ND @ 80	
Exceedences	2	0.1%	Exceedences	2	0.1%	Exceedences	0	0.0%
			Avg Pre-Means:	84.38				
			Avg Post-Means:	80.01				
			Avg % Reduction:	1.47				
Arsenic	Number	Percentages	Arsenic	Number	Percentages	Arsenic	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	34	2.2%	Detects	30	2.2%	Detects	1	1.0%
Nondetects	1510	97.8%	Nondetects	1306	97.8%	Nondetects	102	99.0%
Nondetects @ 20	1505	99.7%	Nondetects @ 20	1306	100.0%	Nondetects @ 20	97	95.1%
Nondetects @ 100	5	0.3%	Nondetects @ 100	0	0.0%	Nondetects @ 100	5	4.9%
Max	286		Max	268		Max	100	
Min	ND @ 20		Min	ND @ 20		Min	ND @ 20	
Exceedences	0	0.0%	Exceedences	0	0.0%	Exceedences	0	0.0%
			Avg Pre-Means:	21.21				
			Avg Post-Means:	20.06				
			Avg % Reduction:	2.09				

Notes: The 'Total' sample numbers do not equal the sum of the 'Clean and Test' and 'Test Only' sample numbers because the 'Matched Pre- and Post-Cleaning Samples' include only the matched pre- and post-cleanup samples collected from the same location.. Similarly, the lead and dioxin sample numbers do not match the sample numbers shown in Tables B-7, B-7a or B-13 because Tables B-7, B-7a and B-13 include all pre-and post-cleanup samples (i.e., residences with only pre- or post-cleanup samples are not excluded from Tables B-7, B-7a and B-13).

Table 3-7. Dust Wipe Sample Data

Table 3-7. Dust Wipe Sample Data								
Total Samples			Matched Pre- and Post-Cleaning Samples			Test Only Samples		
Barium	Number	Percentages	Barium	Number	Percentages	Barium	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	245	15.9%	Detects	210	15.7%	Detects	17	16.5%
Nondetects	1299	84.1%	Nondetects	1126	84.3%	Nondetects	86	83.5%
Nondetects @ 200	1294	99.6%	Nondetects @ 200	1126	100.0%	Nondetects @ 200	81	94.2%
Nondetects @ 1000	5	0.4%	Nondetects @ 1000	0	0.0%	Nondetects @ 1000	5	5.8%
Max	23400		Max	23400		Max	5510	
Min	ND @ 200		Min	ND @ 200		Min	ND @ 200	
Exceedences	0	0.0%	Exceedences	0	0.0%	Exceedences	0	0.0%
			Avg Pre-Means:	367.84				
			Avg Post-Means:	215.12				
			Avg % Reduction:	13.92				
Beryllium	Number	Percentages	Beryllium	Number	Percentages	Beryllium	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	0	0.0%	Detects	0	0.0%	Detects	0	0.0%
Nondetects	1544	100.0%	Nondetects	1336	100.0%	Nondetects	103	100.0%
Nondetects @ 20	1539	99.7%	Nondetects @ 20	1336	100.0%	Nondetects @ 20	98	95.1%
Nondetects @ 100	5	0.3%	Nondetects @ 100	0	0.0%	Nondetects @ 100	5	4.9%
Max	ND @ 100		Max	ND @ 20		Max	ND @ 100	
Min	ND @ 20		Min	ND @ 20		Min	ND @ 20	
Exceedences	0	0.0%	Exceedences	0	0.0%	Exceedences	0	0.0%
			Avg Pre-Means:	20.00				
			Avg Post-Means:	20.00				
			Avg % Reduction:	0.00				
Cadmium	Number	Percentages	Cadmium	Number	Percentages	Cadmium	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	68	4.4%	Detects	50	3.7%	Detects	12	11.7%
Nondetects	1476	95.6%	Nondetects	1286	96.3%	Nondetects	91	88.3%
Nondetects @ 20	1471	99.7%	Nondetects @ 20	1286	100.0%	Nondetects @ 20	86	94.5%
Nondetects @ 100	5	0.3%	Nondetects @ 100	0	0.0%	Nondetects @ 100	5	5.5%
Max	1180		Max	906		Max	1180	
Min	ND @ 20		Min	ND @ 20		Min	ND @ 20	
Exceedences	0	0.0%	Exceedences	0	0.0%	Exceedences	0	0.0%
			Avg Pre-Means:	22.34				
			Avg Post-Means:	20.28				
			Avg % Reduction:	3.13				

Notes: The 'Total' sample numbers do not equal the sum of the 'Clean and Test' and 'Test Only' sample numbers because the 'Matched Pre- and Post-Cleaning Samples' include only the matched pre- and post-cleanup samples collected from the same location. Similarly, the lead and dioxin sample numbers do not match the sample numbers shown in Tables B-7, B-7a or B-13 because Tables B-7, B-7a and B-13 include all pre-and post-cleanup samples (i.e., residences with only pre- or post-cleanup samples are not excluded from Tables B-7, B-7a and B-13).

Table 3-7. Dust Wipe Sample Data

Table 3-7. Dust Wipe Sample Data								
Total Samples			Matched Pre- and Post-Cleaning Samples			Test Only Samples		
Calcium	Number	Percentages	Calcium	Number	Percentages	Calcium	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	1544	100.0%	Detects	1336	100.0%	Detects	103	100.0%
Nondetects	0	0.0%	Nondetects	0	0.0%	Nondetects	0	0.0%
Max	4050000		Max	4050000		Max	474000	
Min	1440		Min	1680		Min	1440	
Exceedences	0	0.0%	Exceedences	0	0.0%	Exceedences	0	0.0%
			Avg Pre-Means:	43239.15				
			Avg Post-Means:	24571.60				
			Avg % Reduction:	28.95				
Chromium	Number	Percentages	Chromium	Number	Percentages	Chromium	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	855	55.4%	Detects	723	54.2%	Detects	63	61.2%
Nondetects	689	44.6%	Nondetects	613	45.8%	Nondetects	40	38.8%
Nondetects @ 20	684	99.3%	Nondetects @ 20	613	100.0%	Nondetects @ 20	35	87.5%
Nondetects @ 100	5	0.7%	Nondetects @ 100	0	0.0%	Nondetects @ 100	5	12.5%
Max	1900		Max	1050		Max	1900	
Min	ND @ 20		Min	ND @ 20		Min	ND @ 20	
Exceedences	0	0.0%	Exceedences	0	0.0%	Exceedences	0	0.0%
			Avg Pre-Means:	48.01				
			Avg Post-Means:	28.23				
			Avg % Reduction:	21.45				
Cobalt	Number	Percentages	Cobalt	Number	Percentages	Cobalt	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	4	0.3%	Detects	2	0.1%	Detects	1	1.0%
Nondetects	1540	99.7%	Nondetects	1334	99.9%	Nondetects	102	99.0%
Nondetects @ 200	1535	99.7%	Nondetects @ 200	1334	100.0%	Nondetects @ 200	97	95.1%
Nondetects @ 1000	5	0.3%	Nondetects @ 1000	0	0.0%	Nondetects @ 1000	5	4.9%
Max	1000		Max	654		Max	1000	
Min	ND @ 200		Min	ND @ 200		Min	ND @ 200	
Exceedences	0	0.0%	Exceedences	0	0.0%	Exceedences	0	0.0%
			Avg Pre-Means:	200.92				
			Avg Post-Means:	200.00				
			Avg % Reduction:	0.29				

Notes: The 'Total' sample numbers do not equal the sum of the 'Clean and Test' and 'Test Only' sample numbers because the 'Matched Pre- and Post-Cleaning Samples' include only the matched pre- and post-cleanup samples collected from the same location. Similarly, the lead and dioxin sample numbers do not match the sample numbers shown in Tables B-7, B-7a or B-13 because Tables B-7, B-7a and B-13 include all pre-and post-cleanup samples (i.e., residences with only pre- or post-cleanup samples are not excluded from Tables B-7, B-7a and B-13).

Table 3-7. Dust Wipe Sample Data

Table 3-7. Dust Wipe Sample Data								
Total Samples			Matched Pre- and Post-Cleaning Samples			Test Only Samples		
Copper	Number	Percentages	Copper	Number	Percentages	Copper	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	1544	100.0%	Detects	1336	100.0%	Detects	103	100.0%
Nondetects	0	0.0%	Nondetects	0	0.0%	Nondetects	0	0.0%
Max	14500		Max	14500		Max	3700	
Min	36		Min	36		Min	108	
Exceedences	0	0.0%	Exceedences	0	0.0%	Exceedences	0	0.0%
			Avg Pre-Means:	387.98				
			Avg Post-Means:	226.82				
			Avg % Reduction:	18.73				
Iron	Number	Percentages	Iron	Number	Percentages	Iron	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	1544	100.0%	Detects	1336	100.0%	Detects	103	100.0%
Nondetects	0	0.0%	Nondetects	0	0.0%	Nondetects	0	0.0%
Max	228000		Max	212000		Max	168000	
Min	207		Min	462		Min	207	
Exceedences	0	0.0%	Exceedences	0	0.0%	Exceedences	0	0.0%
			Avg Pre-Means:	5438.09				
			Avg Post-Means:	1689.07				
			Avg % Reduction:	34.77				
Lead	Number	Percentages	Lead	Number	Percentages	Lead	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	1280	82.9%	Detects	1090	81.6%	Detects	89	86.4%
Nondetects	264	17.1%	Nondetects	246	18.4%	Nondetects	14	13.6%
Nondetects @ 1.86	260	98.5%	Nondetects @ 1.86	246	100.0%	Nondetects @ 1.86	10	71.4%
Nondetects @ 9.29	4	1.5%	Nondetects @ 9.29	0	0.0%	Nondetects @ 9.29	4	28.6%
Max	7250		Max	7250		Max	1380	
Min	ND @ 1.86		Min	ND @ 1.86		Min	ND @ 1.86	
Exceedences	136	8.8%	Exceedences	112	8.4%	Exceedences	12	11.7%
			Avg Pre-Means:	24.40				
			Avg Post-Means:	16.21				
			Avg % Reduction:	8.19				

Notes: The 'Total' sample numbers do not equal the sum of the 'Clean and Test' and 'Test Only' sample numbers because the 'Matched Pre- and Post-Cleaning Samples' include only the matched pre- and post-cleanup samples collected from the same location. Similarly, the lead and dioxin sample numbers do not match the sample numbers shown in Tables B-7, B-7a or B-13 because Tables B-7, B-7a and B-13 include all pre-and post-cleanup samples (i.e., residences with only pre- or post-cleanup samples are not excluded from Tables B-7, B-7a and B-13).

Table 3-7. Dust Wipe Sample Data

Table 3-7. Dust Wipe Sample Data								
Total Samples			Matched Pre- and Post-Cleaning Samples			Test Only Samples		
Magnesium	Number	Percentages	Magnesium	Number	Percentages	Magnesium	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	1544	100.0%	Detects	1336	100.0%	Detects	103	100.0%
Nondetects	0	0.0%	Nondetects	0	0.0%	Nondetects	0	0.0%
Max	1550000		Max	1550000		Max	83400	
Min	2920		Min	4650		Min	3560	
Exceedences	0	0.0%	Exceedences	0	0.0%	Exceedences	0	0.0%
			Avg Pre-Means:	15852.43				
			Avg Post-Means:	11540.41				
			Avg % Reduction:	12.46				
Manganese	Number	Percentages	Manganese	Number	Percentages	Manganese	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	1455	94.2%	Detects	1263	94.5%	Detects	95	92.2%
Nondetects	89	5.8%	Nondetects	73	5.5%	Nondetects	8	7.8%
Nondetects @ 20	85	95.5%	Nondetects @ 20	73	100.0%	Nondetects @ 20	4	50.0%
Nondetects @ 100	4	4.5%	Nondetects @ 100	0	0.0%	Nondetects @ 100	4	50.0%
Max	4410		Max	4410		Max	2390	
Min	ND @ 20		Min	ND @ 20		Min	ND @ 20	
Exceedences	0	0.0%	Exceedences	0	0.0%	Exceedences	0	0.0%
			Avg Pre-Means:	117.82				
			Avg Post-Means:	51.19				
			Avg % Reduction:	30.18				
Mercury	Number	Percentages	Mercury	Number	Percentages	Mercury	Number	Percentages
Samples	1517		Samples	1298		Samples	100	
Detects	593	39.1%	Detects	469	36.1%	Detects	64	64.0%
Nondetects	924	60.9%	Nondetects	829	63.9%	Nondetects	36	36.0%
Nondetects @ 0.4	885	95.8%	Nondetects @ 0.4	793	95.7%	Nondetects @ 0.4	36	100.0%
Nondetects @ 1.6	8	0.9%	Nondetects @ 1.6	7	0.8%	Nondetects @ 1.6	0	0.0%
Nondetects @ 40	2	0.2%	Nondetects @ 40	2	0.2%	Nondetects @ 40	0	0.0%
Nondetects @ 2	20	2.2%	Nondetects @ 2	19	2.3%	Nondetects @ 2	0	0.0%
Nondetects @ 4	9	1.0%	Nondetects @ 4	8	1.0%	Nondetects @ 4	0	
Max	248		Max	248		Max	15.8	
Min	ND @ 0.4		Min	ND @ 0.4		Min	ND @ 0.4	
Exceedences	6	0.4%	Exceedences	5	0.4%	Exceedences	0	0.0%
			Avg Pre-Means:	4.71				
			Avg Post-Means:	2.24				
			Avg % Reduction:	0.84				

Notes: The 'Total' sample numbers do not equal the sum of the 'Clean and Test' and 'Test Only' sample numbers because the 'Matched Pre- and Post-Cleaning Samples' include only the matched pre- and post-cleanup samples collected from the same location. Similarly, the lead and dioxin sample numbers do not match the sample numbers shown in Tables B-7, B-7a or B-13 because Tables B-7, B-7a and B-13 include all pre-and post-cleanup samples (i.e., residences with only pre- or post-cleanup samples are not excluded from Tables B-7, B-7a and B-13).

Table 3-7. Dust Wipe Sample Data

Table 3-7. Dust Wipe Sample Data								
Total Samples			Matched Pre- and Post-Cleaning Samples			Test Only Samples		
Nickel	Number	Percentages	Nickel	Number	Percentages	Nickel	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	613	39.7%	Detects	523	39.2%	Detects	57	55.3%
Nondetects	931	60.3%	Nondetects	813	60.8%	Nondetects	46	44.7%
Nondetects @ 20	928	99.7%	Nondetects @ 20	813	100.0%	Nondetects @ 20	43	93.5%
Nondetects @ 100	3	0.3%	Nondetects @ 100	0	0.0%	Nondetects @ 100	3	6.5%
Max	3160		Max	3160		Max	492	
Min	ND @ 20		Min	ND @ 20		Min	ND @ 20	
Exceedences	0	0.0%	Exceedences	0	0.0%	Exceedences	0	0.0%
			Avg Pre-Means:	62.56				
			Avg Post-Means:	27.13				
			Avg % Reduction:	23.15				
Potassium	Number	Percentages	Postassium	Number	Percentages	Postassium	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	1544	100.0%	Detects	1336	100.0%	Detects	103	100.0%
Nondetects	0	0.0%	Nondetects	0	0.0%	Nondetects	0	0.0%
Max	239000		Max	239000		Max	100000	
Min	1350		Min	1350		Min	8140	
Exceedences	0	0.0%	Exceedences	0	0.0%	Exceedences	0	0.0%
			Avg Pre-Means:	24749.34				
			Avg Post-Means:	20235.38				
			Avg % Reduction:	10.67				
Selenium	Number	Percentages	Selenium	Number	Percentages	Selenium	Number	Percentages
Samples	1544		Samples	1319		Samples	103	
Detects	1204	78.0%	Detects	984	74.7%	Detects	102	99.0%
Nondetects	340	22.0%	Nondetects	334	25.3%	Nondetects	1	1.0%
Nondetects @ 20	280	82.4%	Nondetects @ 20	277	82.9%	Nondetects @ 20	1	100.0%
Nondetects @ 40	60	17.6%	Nondetects @ 40	57	17.1%	Nondetects @ 40	0	0.0%
Max	590		Max	590		Max	559	
Min	ND @ 20		Min	ND @ 20		Min	ND @ 20	
Exceedences	0	0.0%	Exceedences	0	0.0%	Exceedences	0	0.0%
			Avg Pre-Means:	137.85				
			Avg Post-Means:	240.49				
			Avg % Reduction:	-38.53				

Notes: The 'Total' sample numbers do not equal the sum of the 'Clean and Test' and 'Test Only' sample numbers because the 'Matched Pre- and Post-Cleaning Samples' include only the matched pre- and post-cleanup samples collected from the same location. Similarly, the lead and dioxin sample numbers do not match the sample numbers shown in Tables B-7, B-7a or B-13 because Tables B-7, B-7a and B-13 include all pre-and post-cleanup samples (i.e., residences with only pre- or post-cleanup samples are not excluded from Tables B-7, B-7a and B-13).

Table 3-7. Dust Wipe Sample Data

Table 3-7. Dust Wipe Sample Data								
Total Samples			Matched Pre- and Post-Cleaning Samples			Test Only Samples		
Silver	Number	Percentages	Silver	Number	Percentages	Silver	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	26	1.7%	Detects	24	1.8%	Detects	1	1.0%
Nondetects	1518	98.3%	Nondetects	1312	98.2%	Nondetects	102	99.0%
Nondetects @ 20	1512	99.6%	Nondetects @ 20	1311	99.9%	Nondetects @ 20	97	95.1%
Nondetects @ 100	5	0.3%	Nondetects @ 100	0	0.0%	Nondetects @ 100	5	4.9%
Nondetects @ 200	1	0.1%	Nondetects @ 200	1	0.1%	Nondetects @ 200	0	0.0%
Max	1400		Max	1400		Max	268	
Min	ND @ 20		Min	ND @ 20		Min	ND @ 20	
Exceedences	0	0.0%	Exceedences	0	0.0%	Exceedences	0	0.0%
			Avg Pre-Means:	22.49				
			Avg Post-Means:	650.77				
			Avg % Reduction:	-3151.96				
Sodium	Number	Percentages	Sodium	Number	Percentages	Sodium	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	1538	99.6%	Detects	1333	99.8%	Detects	101	98.1%
Nondetects	6	0.4%	Nondetects	3	0.2%	Nondetects	2	1.9%
Nondetects @ 400	2	33.3%	Nondetects @ 400	1	33.3%	Nondetects @ 400	1	50.0%
Nondetects @ 4000	2	33.3%	Nondetects @ 4000	1	33.3%	Nondetects @ 4000	1	50.0%
Max	2	33.3%	Max	1	33.3%	Max	0	0.0%
Min	557000		Min	557000		Min	222000	
Exceedences	ND @ 400		Exceedences	ND @ 400		Exceedences	ND @ 400	
			Avg Pre-Means:	63441.36				
			Avg Post-Means:	51980.14				
			Avg % Reduction:	11.33				
Dioxin (TEQ ND=1/2)	Number	Percentages	Dioxin (TEQ ND=1/2)	Number	Percentages	Dioxin (TEQ ND=1/2)	Number	Percentages
Samples	1538		Samples	1322		Samples	103	
Detects	1136	73.9%	Detects	938	71.0%	Detects	96	93.2%
Nondetects	402	26.1%	Nondetects	384	29.0%	Nondetects	7	6.8%
Max	75.3		Max	2.29		Max	3.01	
Min	0.265		Min	0.265		Min	0.349	
Exceedences	8	0.5%	Exceedences	3	0.2%	Exceedences	1	1.0%
			Avg Pre-Means:	0.65				
			Avg Post-Means:	0.64				
			Avg % Reduction:	0.01				

Notes: The 'Total' sample numbers do not equal the sum of the 'Clean and Test' and 'Test Only' sample numbers because the 'Matched Pre- and Post-Cleaning Samples' include only the matched pre- and post-cleanup samples collected from the same location. Similarly, the lead and dioxin sample numbers do not match the sample numbers shown in Tables B-7, B-7a or B-13 because Tables B-7, B-7a and B-13 include all pre-and post-cleanup samples (i.e., residences with only pre- or post-cleanup samples are not excluded from Tables B-7, B-7a and B-13).

Table 3-7. Dust Wipe Sample Data

Table 3-7. Dust Wipe Sample Data								
Total Samples			Matched Pre- and Post-Cleaning Samples			Test Only Samples		
Thallium	Number	Percentages	Thallium	Number	Percentages	Thallium	Number	Percentages
Samples	1544		Samples	938		Samples	103	
Detects	0	0.0%	Detects	0	0.0%	Detects	0	0.0%
Nondetects	1544	100.0%	Nondetects	938	100.0%	Nondetects	103	100.0%
Nondetects @ 200	1539	99.7%	Nondetects @ 200	938	100.0%	Nondetects @ 200	98	95.1%
Nondetects @ 1000	5	0.3%	Nondetects @ 1000	0	0.0%	Nondetects @ 1000	5	4.9%
Max	ND @ 1000		Max	ND @ 200		Max	ND @ 1000	
Min	ND @ 200		Min	ND @ 200		Min	ND @ 200	
Exceedences	0	0.0%	Exceedences	0	0.0%	Exceedences	0	0.0%
			Avg Pre-Means:	235.80				
			Avg Post-Means:	195.51				
			Avg % Reduction:	3.85				
Vanadium	Number	Percentages	Vanadium	Number	Percentages	Vanadium	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	7	0.5%	Detects	3	0.2%	Detects	1	1.0%
Nondetects	1537	99.5%	Nondetects	1333	99.8%	Nondetects	102	99.0%
Nondetects @ 200	1532	99.7%	Nondetects @ 200	1333	100.0%	Nondetects @ 200	97	95.1%
Nondetects @ 1000	5	0.3%	Nondetects @ 1000	0	0.0%	Nondetects @ 1000	5	4.9%
Max	1000		Max	539		Max	1000	
Min	ND @ 200		Min	ND @ 200		Min	ND @ 200	
Exceedences	0	0.0%	Exceedences	0	0.0%	Exceedences	0	0.0%
			Avg Pre-Means:	236.67				
			Avg Post-Means:	641.60				
			Avg % Reduction:	-218.87				
Zinc	Number	Percentages	Zinc	Number	Percentages	Zinc	Number	Percentages
Samples	1544		Samples	1336		Samples	103	
Detects	1544	100.0%	Detects	1336	100.0%	Detects	103	100.0%
Nondetects	0	0.0%	Nondetects	0	0.0%	Nondetects	0	0.0%
Max	78900		Max	78900		Max	67400	
Min	372		Min	539		Min	380	
Exceedences	0	0.0%	Exceedences	0	0.0%	Exceedences	0	0.0%
			Avg Pre-Means:	2196.83				
			Avg Post-Means:	1419.72				
			Avg % Reduction:	16.89				

Notes: The 'Total' sample numbers do not equal the sum of the 'Clean and Test' and 'Test Only' sample numbers because the 'Matched Pre- and Post-Cleaning Samples' include only the matched pre- and post-cleanup samples collected from the same location. Similarly, the lead and dioxin sample numbers do not match the sample numbers shown in Tables B-7, B-7a or B-13 because Tables B-7, B-7a and B-13 include all pre-and post-cleanup samples (i.e., residences with only pre- or post-cleanup samples are not excluded from Tables B-7, B-7a and B-13).

The database contained 1,517 results for mercury, and 1,544 results for all of the other metals. The rate of detection (based on all samples) varied widely from 0 for beryllium and thallium, to 100% for calcium, copper, iron, magnesium, potassium and zinc. Eight of the 21 metals had detection rates of less than or equal to 5%; 4 had detection rates between 6 and 60%. Results for each metal were compared against risk-based screening levels (Table 3-8). Very few exceedances of the risk-based screening values were measured for any of the metals. The screening value of $627 \mu\text{g}/\text{m}^2$ for antimony was exceeded in 2 pre-cleanup samples (0.1% of all samples); the maximum measured value was $1,180 \mu\text{g}/\text{m}^2$. The screening value of $157 \mu\text{g}/\text{m}^2$ for mercury was exceeded in 5 pre-cleanup samples (0.4% of all samples). No residence had an average antimony dust loading or mercury dust loading greater than their respective health-based benchmarks.

3.2 EFFICACY OF THE DUST CLEANUP PROGRAM

3.2.1 Reductions in the Rate of PCMe Exceedances

The efficacy of the asbestos cleanup effort was assessed using PCMe exceedances for *clean and test* data. One measure of effectiveness is the overall rate of exceedances, which equals the number of exceedances divided by the total number of samples that were collected. The overall exceedance rate on sample-basis for the WTC cleanup program was approximately 0.00418, or 0.42%.

An alternative measure of efficacy is the number of times a residence or a common area within a building (e.g., hallway, stairwell, laundry) had to be recleaned to achieve the clearance criteria of 0.0009 f/cc. Residences were recleaned if one or more samples exceeded the health-based benchmark for asbestos, or one or more samples could not be analyzed in the laboratory due to excessive dust on the air filter (i.e., *overloads*). The cleanup effort was effective in achieving the clearance criteria for PCMe approximately 99% of the time in residential units and common areas. The PCMe clearance criterion was not achieved in 35 out of 3,387 (1.03%) residences and in 11 out of 785 common areas (1.40%) after the first cleaning. The probability of achieving the clearance on the second attempt in residential units that did not achieve clearance after the first cleaning was approximately 1 (>0.999; 2 out of the 25 residences that were recleaned did not achieve clearance after the second cleaning - 10 residents elected not to have their residences recleaned, or were unresponsive). These results suggest that the cleaning methods used were effective in reducing asbestos concentrations in residential air.

Table 3-8. Health-based Benchmarks and Screening Values for Chemicals of Potential Concern (COPCs) in Settled Dust.	
Chemical of Potential Concern	Health-based Benchmark/ Screening Value
Aluminum	1567888
Antimony	627
Arsenic	387
Barium	109752
Beryllium	3136
Cadmium	1557
Chromium	4704
Cobalt	31358
Copper	62716
Iron	940733
Lead ^a	25
Manganese	31358
Mercury	157
Nickel	31358
Selenium	7839
Silver	7839
Thallium	110
Vanadium	10975
Zinc	470366
Dioxin ^a	2

Table is based on Table A-3 in EPA, May 2003 COPC report. All benchmarks are $\mu\text{g}/\text{m}^3$, except for lead, which is in $\mu\text{g}/\text{ft}^2$, and dioxin, which is ng/m^2 .

^aThe health-based benchmark for lead is $40 \mu\text{g}/\text{ft}^2$; however, the more stringent screening HUD screening value of $25 \mu\text{g}/\text{ft}^2$ was used (see Section 3.5.1 for details).

^bHealth-based benchmark is for toxicity equivalent (TEQ), which is a weighted summation of 17 types (congeners) of dioxin, where the weights represent the relative toxicity for each specific congener.

A *modified aggressive* sampling procedure was used in most of the apartments (EPA, 2003a). The modified-aggressive sampling procedure was adapted from the aggressive sampling procedure described in AHERA. The aggressive sampling procedure had a tendency to overload the sampling filter with dust, preventing the samples from being analyzed by the laboratory (EPA, 2003a). The modified aggressive sampling is thought to be more representative of typical household activity patterns (EPA, 2003a). The rate of exceedance varied between the two sampling procedures. On a sample basis, the exceedances rates in *test only* residences were 0.50 and 0.49% for the aggressive and modified aggressive sampling procedures, respectively; the exceedances rates for the *clean and test* residences were 3.4 and 0.20% for the aggressive and modified aggressive sampling procedures, respectively. The test only exceedances rates were not significantly different by Fisher's exact test ($p>0.99$); the *clean and test* exceedances rates were statistically significant by Fisher's exact test ($p<0.01$). On a residence-basis (i.e., one or more sample result from the residence equal or exceeded the benchmark for asbestos), the exceedances rates in *test only* residences were 3.0 and 1.1% for the aggressive and modified aggressive sampling procedures, respectively; the exceedances rates for the *clean and test* residences were 6.4 and 0.64% for the aggressive and modified aggressive sampling procedures, respectively. The *test only* exceedances rates were not significantly different by Fisher's exact test ($p>0.34$); the *clean and test* exceedances rates were statistically significant by Fisher's exact test ($p<0.01$).

3.2.2 Reduction in Dust Lead Loading

The methods used were effective in reducing levels of lead as measured by wipe samples. The indoor environment is considered to be a complex and dynamic system that is influenced by many interacting factors (physical, chemical, thermodynamic conditions, human activity, building design, building materials, HVAC system, etc.). Therefore, it is not uncommon to find variability in the amount of contaminants in settled dust within a building, and certainly from one building to the next. In addition to WTC proximity, high variability is also likely due to the wide range of diversity in the housing stock, contents of the residences and common areas, and preexisting conditions, or previous activity, at these sites.

To assess the effectiveness of the cleanup program, the wipe data were divided into two groups: samples that were collected before the apartments were cleaned (*pre-cleanup*), and samples that were collected after the apartments were cleaned (*post-cleanup*). Pre-cleanup lead wipe samples and post cleanup samples were collected from 214 apartments, located in 145 buildings.

The cleanup program reduced the average dust lead loading in residential units by approximately 16 $\mu\text{g}/\text{ft}^2$ (20%) (Section B.4.1).

Thirty-six residences had pre-cleanup average dust lead loadings greater than the HUD screening of 25 $\mu\text{g}/\text{ft}^2$. Average post-cleanup dust lead loading in residences with average pre-cleanup loadings above the HUD screening level of 25 $\mu\text{g}/\text{ft}^2$ were approximately 85 $\mu\text{g}/\text{ft}^2$ lower than pre-cleanup loadings. The cleanup program was successful in reducing the average dust lead loading in 31 of the 36 residences to below the 25 $\mu\text{g}/\text{ft}^2$ screening level, a success rate of approximately 86% (Section B.4.2).

Twenty-three residences had pre-cleanup average dust lead loadings greater than the HUD benchmark of 40 $\mu\text{g}/\text{ft}^2$. Average post-cleanup dust lead loading in residences with average pre-cleanup loadings above the HUD benchmark of 40 $\mu\text{g}/\text{ft}^2$ were approximately 120 $\mu\text{g}/\text{ft}^2$ lower than average pre-cleanup loadings. The cleanup program reduced the average dust lead loading in 21 out of the 23 residences, a success rate of approximately 91%.

Residences located on the third floor or lower tended to have higher pre-cleanup average loadings (39.52 $\mu\text{g}/\text{ft}^2$) than residences located on floors 4-10 (21.08 $\mu\text{g}/\text{ft}^2$) and floors higher than 10 (14.18 $\mu\text{g}/\text{ft}^2$). Reduction in average dust lead loading also varied by building floor level. On average, dust lead loadings were reduced by 33.1 $\mu\text{g}/\text{ft}^2$ (43.5%) for residences on floors 3 and lower, by 11.1 $\mu\text{g}/\text{ft}^2$ (23.1%) for residences on floors 4-10, and by 6.9 (8.6%) for residences located on floors 11 and higher (Section B.4.3).

The number of exceedances of dust lead loading on a *sample-basis* is shown in Figure 3-1. Two sets of bars are also shown for dust lead loading exceedances, corresponding to two different benchmarks for dust lead loading. The first set of bars corresponds to the WTC screening level of 25 $\mu\text{g}/\text{ft}^2$; the second set corresponds to the HUD health-based benchmark of 40 $\mu\text{g}/\text{ft}^2$. Regardless of the benchmark that is used, the reduction in the number of exceedances (on a sample-basis) is approximately 85%.

3.2.3 Reduction in Dust Dioxin Loading

The measurable effect of the cleanup program on dust dioxin loadings was less than it was for lead due primarily to low pre-cleanup dust dioxin loadings, which limits the usefulness of the dioxin data to assess the efficacy of the dust cleanup program. Pre-cleanup and post cleanup dust wipe samples for dioxin were collected from 212 apartments, located in 145 buildings. Reductions in dust dioxin loadings were modest due to the low pre-cleanup levels. The mean of the average pre-cleanup dust dioxin loading in

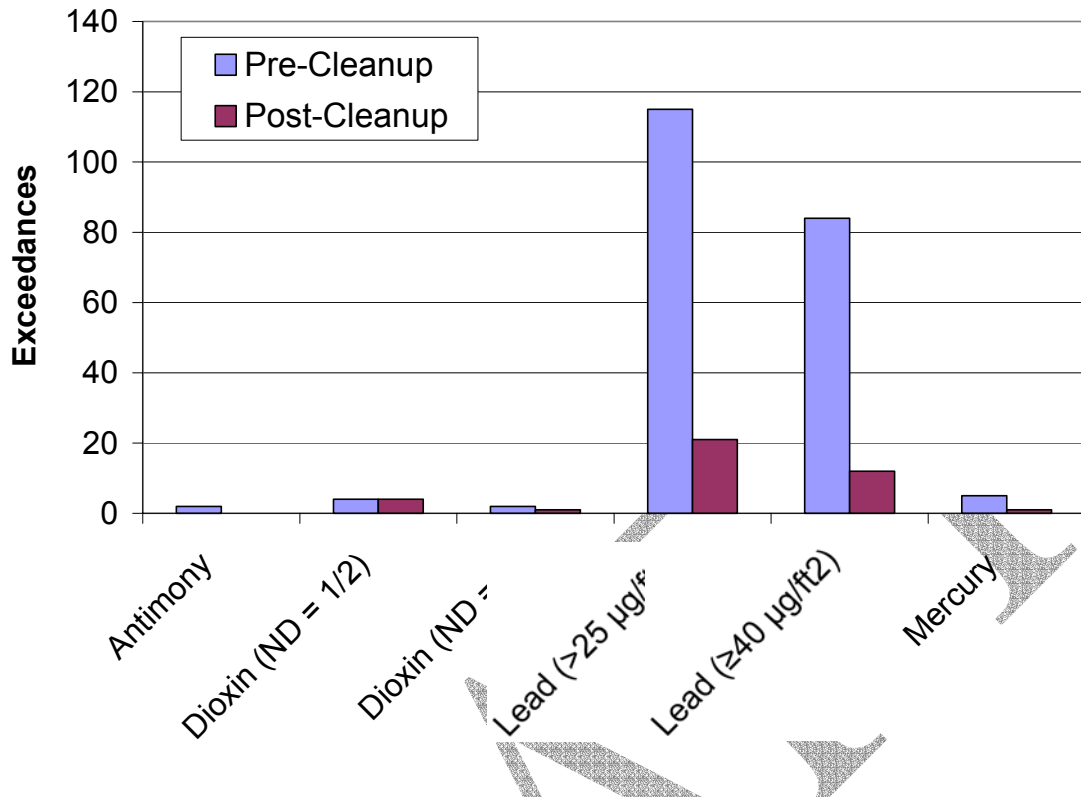


Figure 3-1. The number of *samples* (i.e., not residences) that exceeded health-based benchmarks, for contaminants that had at least one exceedance of their respective health-based benchmark. Two sets of bars are shown for dioxin, corresponding to two methods for treating the dioxin sample results that were reported as below detection limit (*nondetects*) by the laboratory. The first set of numbers (i.e., ND=1/2) corresponds to the method that was used in this report (nondetects were set equal to 1/2 of the detection limit); the second set of numbers corresponds to an alternative method of treating nondetects (setting nondetects equal to 0 ng/m²). The number of exceedances is low regardless of the method that is used to treat the nondetects. Two sets of bars are also shown for dust lead loading exceedances, corresponding to two different benchmarks for dust lead loading. The first set of bars corresponds to the WTC screening level of 25 µg/ft²; the second set corresponds to the HUD health-based benchmark of 40 µg/ft². The reductions in the number of exceedances (pre-cleanup, post-cleanup) are as follows: antimony (2, 0); dioxin (ND=1/2) (4, 4); dioxin (ND=0) (2, 1); lead (>25 µg/ft²) (115, 21); lead (≥ 40 µg/ft²) (84, 12); mercury (5, 1).

each residence was 0.65 ng/m^2 ; all residential average dust dioxin loadings were less than the health-based benchmark of 2 ng/m^2 . The cleanup program reduced the residential average dust dioxin loading by approximately 0.01 ng/m^2 (Section B.4.4).

The number of exceedances of dust dioxin loading on a *sample-basis* is shown in Figure 3-1. Two sets of bars are shown for dioxin, corresponding to two methods for treating the dioxin sample results that were reported as below detection limit (*nondetects*) by the laboratory. The first set of numbers (i.e., $\text{ND}=1/2$) corresponds to the method that was used in this report (nondetects were set equal to $1/2$ of the detection limit); the second set of numbers corresponds to an alternative method of treating nondetects (setting nondetects equal to 0 ng/m^2). The number of exceedances is low regardless of the method that is used to treat the nondetects.

3.2.4 Reduction in Dust Antimony Loading and Dust Mercury Loading

A comparison of the number of exceedances in pre-cleanup *samples* (*not* residences) to the number of exceedances in post-cleanup samples for antimony and mercury is provided in Figure 3-1. The number of dust antimony exceedances was reduced from 2 in the pre-cleanup samples to 0 in the post-cleanup samples; the number of dust mercury exceedances was reduced from 5 in the pre-cleanup samples to 1 in the post-cleanup samples.

3.3 SUMMARY OF THE SPATIAL ANALYSIS OF PCMe EXCEEDANCES

One hundred twenty two of the 28702 samples collected had exceedances of the health based standard ($\text{PCMe} > 0.0009 \text{ f/cc}$) for asbestos. The comparison of the rates of PCMe exceedances between SSAs was restricted to a subset of the SSAs that had a sample size of 30 or more. Sample sizes less than 30 were considered to small to yield reliable results. The existence of a spatial pattern in the PCMe exceedances is not supported by the spatial analyses:

1. Analysis of the site-level (global) pattern of PCMe exceedances indicates that the geographic centers of the exceedance events for the *test only* and *clean and test* buildings tended to be located south of the geographic center of the sampled buildings, and east of the WTC site. Except for one location, the *test only* exceedance locations occurred along an east-west line located south of the WTC site. There is no obvious pattern to the *clean and test* exceedances. Interpretation of the exceedance locations is complicated by the variability in the number of samples that were collected in buildings (Section B.3.2.1).

2. The analysis of PCMe exceedances at the statistical summary area (SSA) level indicated that the rate of PCMe exceedances varied over the sampled area:
 - a. SSAs with similar PCMe exceedance rates tended to be located near each other (i.e., the rates exhibit positive spatial autocorrelation) (Section B.3.2.2).
 - b. Comparison of the rates of PCMe exceedances across the SSAs indicated that SSAs with exceedance rates that were significantly greater than the other SSAs were located east (*test only* data), and north and east (*clean and test* data) of the WTC site (Section B.2.2.2).
3. Analysis of the building-level (local) pattern of PCMe exceedances, using nearest neighbor methods, suggests the pattern is consistent with a spatially random process (Section B.3.2.3).
4. Analysis of the building-level (local) pattern of PCMe exceedances, using Ripley's K function, also failed to reject the hypothesis that the PCMe exceedances were generated by a spatially random process (Section B.3.2.3).
5. Analysis of the site-level vertical distribution of PCMe exceedances, on a residence-basis, did not find any statistically significant pattern for residences that were tested (i.e., *test only* residences) or residences that were cleaned and tested (i.e., *clean and test* residences) (Section B.3.2.4).
6. Analysis of the site-level vertical distribution of PCMe exceedances, on a sample-basis, indicates samples collected from *clean and test* residences and common areas that were located on lower floors (i.e., $\leq 3^{\text{rd}}$ floor) were approximately 2 times more likely to exceed the health-based benchmark for airborne asbestos than were samples collected from *clean and test* residences and common areas located on upper floors (floors 10 and higher). No significant differences were found between *clean and test* samples collected on middle floors (floors 4–9) and upper floors. The rate of PCMe exceedances was found to differ between floor groups for the *test only* samples, although comparisons between the floor groups were not statistically significant (Section B.3.2.4).

3.4 COMPARISON OF WTC INDOOR DUST PROGRAM AND EPA BACKGROUND STUDY

As described earlier, a background study was conducted in Upper Manhattan to determine indoor concentrations of selected analytes that were identified in WTC-related dust. Several of the analytes, specifically asbestos, lead, and dioxin, that were measured in Upper Manhattan were also measured in the WTC Indoor Dust Program. An evaluation was conducted with these three analytes to determine if the concentrations detected in Lower Manhattan one to two years after the collapse of the WTC were similar to those measured in Upper Manhattan. The evaluation consists of comparing the frequency of detection, the range of values reported (i.e., minimum and maximum), and the percentage of samples that were above the health-based benchmark for each analyte (Table 3-9).

The most appropriate measurements for comparison are the frequency of detection and the percentage of samples that exceeded the health-based benchmark. The minimum and maximum values are not the most reliable method for comparing the two studies due to the variability in the detection limits and the substantial difference in sample size between the two studies. As sample size increases there is a tendency for the range of values detected to increase, which limits the reliability of comparing maximum values from the two studies.

In addition to comparing the two studies with each other, the results from the studies were compared to values obtained from the literature. Studies were identified that reported concentrations from indoor environments for these three analytes using similar sampling and analytical methodologies. The minimum, maximum, mean, median, and 90th percentile values from the literature were compared with the values reported from the EPA studies. The literature values were reported using censored data. In order to make the comparison the EPA data compatible with the literature values, the EPA data sets for each analyte were censored using the same method as reported in the literature. This was done for comparison purposes only and the censoring method employed does not provide any additional insight into what the actual values from the EPA studies may have been. The censoring method used, as well as detailed information from each literature study that was chosen for comparison, are presented in the discussion of each analyte.

Asbestos - The frequency of detection from samples collected in the two distinctly different geographic locations were similar, with a detection rate of 2% in Lower Manhattan and 5% in Upper Manhattan. The minimum concentrations from both areas were identical, while the maximum detected concentration in Lower Manhattan was higher than the maximum detected concentration in Upper Manhattan. Although

Table 3-9. Comparison of descriptive statistics from the USEPA WTC Indoor Dust Program and the USEPA Upper Manhattan Background Study.

Comparison of airborne asbestos, dust lead loading and dust dioxin loading measured in Lower Manhattan to concentrations measured in in Upper Manhattan ('background'). The most appropriate measurements for comparison are the frequency of detection and the percentage of samples that exceeded the health-based benchmark. Comparison of the minimum values is confounded by the variability in the detection limits. Comparison of the maximum values is confounded by the variability in sample sizes; as sample size increases there is a tendency for the maximum value to increase.

Analyte	USEPA WTC Indoor Dust Program					USEPA Upper Manhattan Background Study				
	n	% det. ^a	min	max	% above ^b	n	% det. ^a	min	max	% above ^b
Asbestos (s/cc) ^c	20,887	2%	<0.0004	0.0204	0.5%	62	5%	<0.0004	0.0004	0.0%
Lead (µg/ft ²)	1812	78%	<1.86	2530	7.6%	114	50%	<0.5	49	0.9%
Dioxin (ng/m ²) ^d	1549	74%	0.292	5.14	0.5%	114	77%	0.475	1.66	0%

s/cc: structures per cubic centimeters; : g/ft² = micrograms of lead per square foot of surface; ng/m² = nanograms of dioxin per square meter of surface

^a% det.: percent of samples that contained the contaminant at levels above the detection limit

^b% above: percent of sample measurements that were greater than the health-based benchmark (health-based benchmarks:

asbestos: 0.0009 f/cc; lead: 25 µg/ft²; dioxin 2 ng/m²).

^c Phase contrast microscopy equivalent (PCMe) results; see glossary for definition

^d International toxicity equivalent quotient (TEQ) see glossary for definition; all congeners that were not detected were set equal to ½ their detection limit.

the maximum detected concentrations were not similar between the two areas, the percentage of samples that exceeded the health-based criterion was similar, with 0.5% in Lower Manhattan and 0.0% in Upper Manhattan.

A summary paper by the Health Effects Institute presented asbestos results for several different types of buildings, including schools, residences, and public/commercial spaces (HEI-AR, 1991). The asbestos measurements were made using TEM analysis, and counted fibers that were $\leq 5 \mu\text{m}$, which is the same method that was utilized in the EPA studies. The values reported in the summary paper were left-censored; a value of zero was substituted for samples that were reported as being below the detection limit. Values reported for residential spaces, and for all buildings combined (i.e., minimum, mean, median, and 90th percentile) in this summary paper were plotted beside the same values from the EPA studies (Figure 3-2). The horizontal axis reports the results from the test-only data set from Lower Manhattan (LM-Pre), the clean and test data set from Lower Manhattan (LM-Post), the Upper Manhattan data set (UM), the residential data set (Residence) and the data set from all buildings (All) from the HEI summary paper. The results of this comparison indicate that all of the values that were plotted fall below the health-based benchmark that was established for the WTC Indoor Dust Cleanup program. The only exception is the maximum values that were reported for the Lower Manhattan data set, which were above the health-based benchmark. The maximum values from the literature were not reported, so a comparison cannot be made. The mean values from the literature are higher than those reported in the EPA studies (after replacing non-detects with 0). This may be in part due to the high number of non-detect samples that were present in the EPA studies. If the detection limit were substituted for the EPA non-detect samples, the means from the EPA studies would be near 0.0005 s/cc. It is likely that the true mean asbestos concentration in Manhattan, based on data from the EPA studies, lies somewhere between 0 and 0.0005 s/cc. The middle of the range, which is 0.00025 s/cc, is quite similar to the mean reported in the HEI summary paper.

Lead - The frequency of detection, the maximum detected concentration, and the percentage of samples that exceeded the health-based criteria were higher in Lower Manhattan when compared to the results from Upper Manhattan¹. If only the post-cleaning samples from the clean and test apartments are used for the comparison, the percentage above the health-based criterion falls from 7.6% to 2.5%, which is more similar to the Upper Manhattan rate (0.9%).

¹ Two data points were removed from the Lower Manhattan data set for this analysis, as they were identified as outliers in the lead data set.

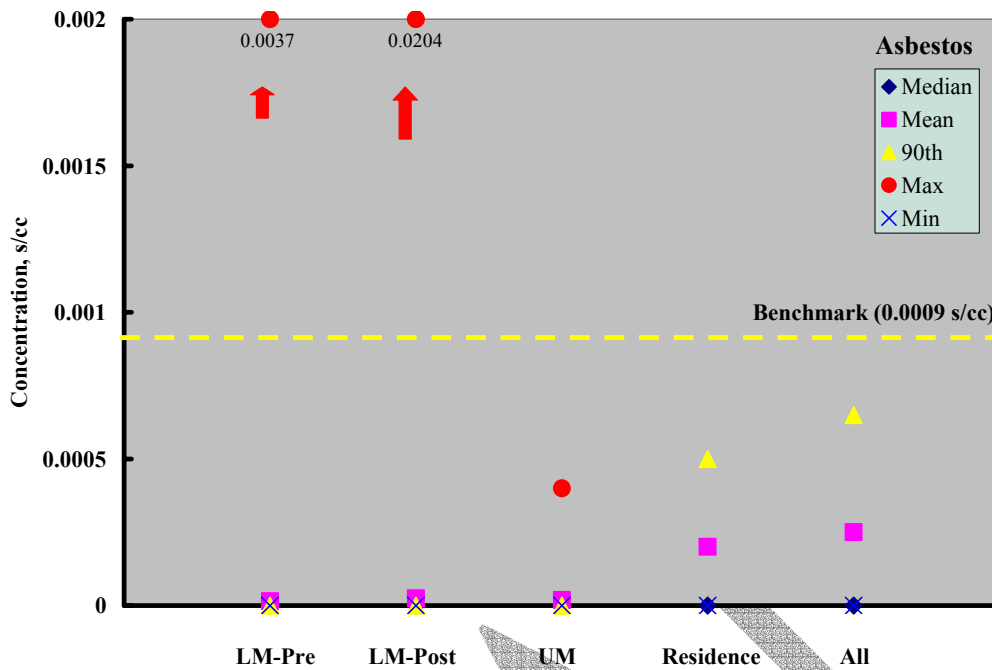


Figure 3-2. Comparison of airborne asbestos concentrations from WTC Dust Cleanup Program and Background Study to concentrations reported by the Health Effects Institute (HEI, 1991). The table includes data from the test-only data (LM-Pre), and clean and test data (LM-Post) from the Lower Manhattan Dust Cleanup Program; Upper Manhattan data (i.e., background) (UM) from the WTC Background Study (EPA, 2003b); and, the residential data (Residence) and the data from all buildings (All) from the HEI summary paper (HEI, 1991). The results of this comparison indicate that all of the values fall below the health-based benchmark that was established for the WTC Indoor Dust Cleanup program. The only exception is the maximum values that were reported for the Lower Manhattan data set, which were above the health-based benchmark. The maximum values from the literature were not reported, so a comparison cannot be made. The mean values from the literature are higher than those reported in the USEPA studies (after replacing non-detects with 0). This may be in part due to the high number of non-detect samples that were present in the USEPA studies. If the detection limit were substituted for the USEPA non-detect samples, the means from the USEPA studies would be near 0.0005 s/cc. Its likely that the true mean asbestos concentration in Manhattan, based on data from the USEPA studies, lies somewhere between 0 and 0.0005 s/cc. An estimate that is in the middle of the that range, e.g., 0.00025 s/cc, is quite similar to the mean reported in the HEI summary paper.

The best comparison data set that was identified for lead was the 2001 Housing and Urban Development database for lead and allergens in U.S. housing (HUD, 2001). This database provides data on lead in settled dust from urban residences in four regions of the United States (i.e., Northeast, Midwest, South, and West), by building age. Information on the distribution of lead loadings for carpeted and uncarpeted floors in housing stock ranging in age from pre-1939 to 1998 for the Northeast was queried from the HUD database and descriptive statistics were generated. Values for samples that were identified as being below the detection limit were substituted with $\frac{1}{2}$ of the detection limit. The minimum, maximum, median, mean, and 90th percentile values were plotted beside the same values from the USEPA studies (Figure 3-3). The horizontal axis reports the results from the test-only data set from Lower Manhattan (LM-Pre), the clean and test data set from Lower Manhattan (LM-Post), the Upper Manhattan data set (UM), and the HUD data set. The maximum values detected in the LM-Pre and HUD data sets were similar, although the LM-Pre value was higher. The means from the four data sets were all below the health-based benchmark. The LM-Pre mean was just under the benchmark, the LM-Post and HUD means were similar, and the UM mean was the lowest. The comparison indicates that the maximum detected concentrations varied between studies, the means, medians, and 90th percentile values for the LM-Post, UM, and HUD were below the benchmark, and all but the 90th percentile for the LM-Pre data set were below the benchmark.

Dioxin - The frequency of detection in the two areas were similar with a rate of 74% in Lower Manhattan and 77% in Upper Manhattan. The minimum detected concentrations were also similar, and the maximum detected concentration from Lower Manhattan was slightly higher than Upper Manhattan². The percentage of samples that were above the health-based criterion was similar between the two areas with a rate of 0.5% in Lower Manhattan and 0.0% in Upper Manhattan.

There was limited information in the literature for dioxin wipe samples that could be used for comparison. The New York State Department of Health (NYSDOH) reported on post-occupancy environmental sampling from an office building that was impacted by a fire that released polychlorinated biphenyls and dioxin (NYSDOH, 2002). This report presented data (Binghamton data) for wipe samples that were collected and analyzed for dioxin using similar methods as those used in the EPA studies. The data represents the seventh round of post-occupancy sampling, which occurred in 1999, 18 years after the building fire. This was the last round of sampling because the dioxin concentrations were very low

² One data point was removed from the Lower Manhattan data set for this analysis, as it was identified as outliers in the dioxin data set.

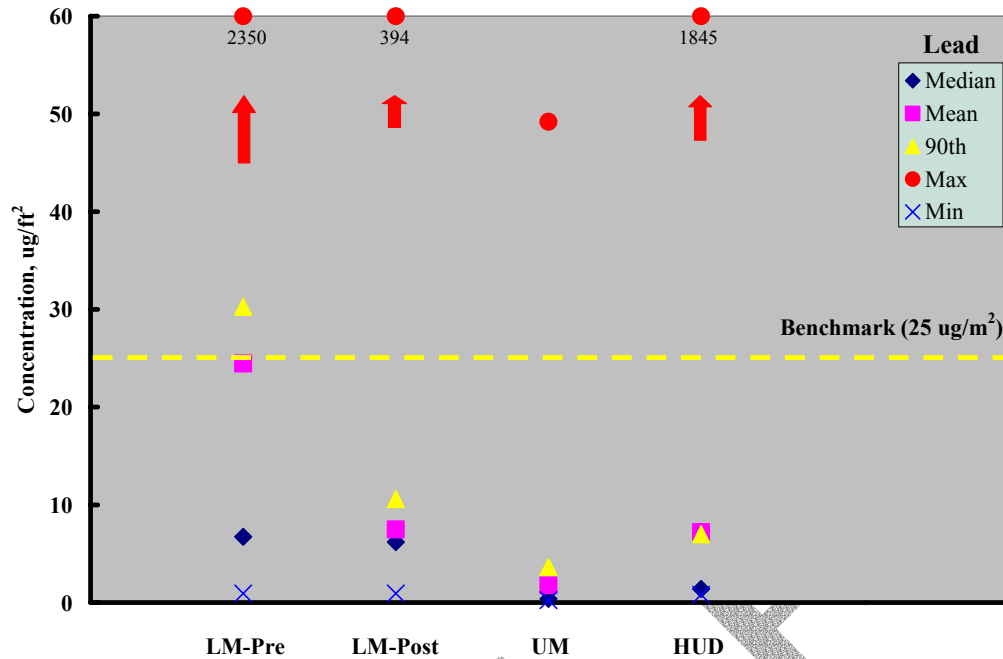


Figure 3-3. Comparison of dust lead loading levels from WTC Dust Cleanup Program and Background Study to loadings reported in the HUD Survey of Lead and Allergens in U.S. Housing database (HUD, 2001). Data for carpeted and uncarpeted buildings in the Northeast constructed from pre-1939 to 1998 were used in this analysis. The figure includes data from the test-only data (LM-Pre), and clean and test data (LM-Post) from the Lower Manhattan Dust Cleanup Program; Upper Manhattan data (i.e., background) (UM) from the WTC Background Study (EPA, 2003b); and, the data from the HUD database (HUD, 2001). Values for samples that were identified as being below the detection limit were substituted with $\frac{1}{2}$ of the detection limit. The maximum values detected in the LM-Pre and HUD data sets were similar, although the LM-Pre value was higher. The means from the four data sets were all below the health-based benchmark. The LM-Pre mean was just under the benchmark, the LM-Post and HUD means were similar, and the UM mean was the lowest. The comparison indicates that the maximum detected concentrations varied between studies, the means, medians, and 90th percentile values for the LM-Post, UM, and HUD were below the benchmark, and all but the 90th percentile for the LM-Pre data set were below the benchmark.

throughout the building. The values presented in the paper were reported in Toxicity Equivalents Quotients (TEQs) where congeners that were below the detection limit were set to $\frac{1}{2}$ of the detection limit. The minimum, maximum, median, mean, and 90th percentile values from this study were plotted beside the same values from the EPA studies (Figure 3-4). The minimum, median, and mean values from the three studies were very similar. There was a slightly higher value for the 90th percentile from the NYSDOH data set (NYSDOH, 2002). The minimum, median, mean, and 90th percentile values were all below the health-based benchmark. The maximum detected concentrations from the Lower Manhattan data sets (LM-Pre and LM-Post) were marginally higher than the Upper Manhattan (UM) and Binghamton data sets. With the exception of the UM data set, all of the maximum values were above the health-based benchmark. This indicates that the dioxin concentrations observed in the WTC Indoor Dust Program were similar to background, and similar to values reported in the literature.

In summary, a comparison between analytical results from Lower Manhattan and Upper Manhattan show that the number of samples that exceed health-based criteria for three analytes one to two years after the collapse of the WTC are similar. Additionally, values reported in the literature for these analytes indicate that the mean, median, and 90th percentile values are similar to those reported in the EPA studies, with the exception of maximum detected concentrations which were generally higher than those reported in the literature.

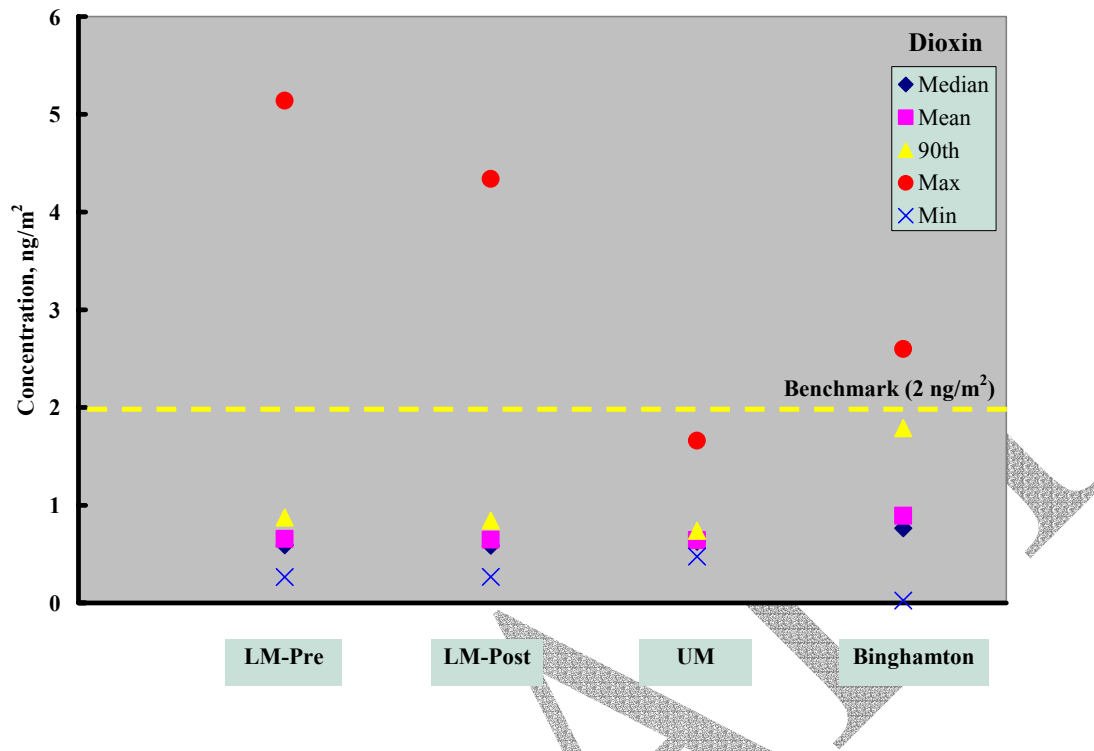


Figure 3-4. Comparison of dust dioxin loading levels from WTC Dust Cleanup Program and Background Study to loadings measured in an office building in Binghamton, NY by the New York State Department of Health (NYSDOH, 2002). The figure includes data from the test-only data (LM-Pre), and clean and test data (LM-Post) from the Lower Manhattan Dust Cleanup Program; Upper Manhattan data (i.e., background) (UM) from the WTC Background Study (EPA, 2003b); and, data from (NYSDOH, 2002). The minimum, median, and mean values from the three studies were very similar. There was a slightly higher value for the 90th percentile from the NYSDOH data set (NYSDOH, 2002). The minimum, median, mean, and 90th percentile values were all below the health-based benchmark. The maximum detected concentrations from the Lower Manhattan data sets (LM-Pre and LM-Post) were marginally higher than the Upper Manhattan (UM) and Binghamton data sets. With the exception of the UM data set, all of the maximum values were above the health-based benchmark. This indicates that the dioxin concentrations observed in the WTC Indoor Dust Program were similar to background, and similar to values reported in the literature.

References

- Agency for Toxic Substances and Disease Registry/New York City Department of Health and Mental Hygiene (ATSDR/NYCDOHMH). 2002. Final Report of the Public Health Investigation to Assess Potential Exposures to Airborne and Settled Surface Dust in Residential Areas of Lower Manhattan, September.
- Bailey, T.C. and A.C. Gatrell. 1995. Interactive Spatial Data Analysis. Prentice Hall. Harlow, England.
- Cameron, A. and P. Trivedi. 1998. Regression analysis of count data. Cambridge University Press.
- Clark, P.J. and F.C. Evans. 1954. Distance to Nearest Neighbor as a Measure of Spatial Relationships in Populations. *Ecology* (35)4.
- Cressie, N.A.C. 1993. Statistics for Spatial Data. John Wiley & Sons, Inc. New York, N.Y.
- Dixon, P.M. 2001. Nearest Neighbor Methods. Department of Statistics, Iowa State University. Preprint #01-19 December 1.
- Ebdon, D. Statistics in Geography. 1988. Basil Blackwell, Ltd., Oxford, UK.
- Ground Zero Taskforce. 2001. Characterization of Particulate Found In Apartments After Destruction of the World Trade Center, October.
- Griffith, D. and J. Layne. 1999. A casebook for spatial statistical data analysis. Oxford University Press, NY.
- Griffith, D. 2002. A spatial filtering specification for the auto-Poisson model. *Statistics & Probability Letters* 58:245-251.
- Health Effects Institute – Asbestos Research (HEI-AR). 1991. Asbestos in Public and Commercial Buildings: A literature review and synthesis of current knowledge. <http://www.asbestos-institute.ca/reviews/hei-ar/hei-ar.html>.
- Hope, A. (1968). A simplified Monte Carlo significance test procedure, *J. of the Royal Statistical Society*, 30B: 582-598.
- Levine, N. 2002. CrimeStat II: A Spatial Statistics Program for the Analysis of Crime Incident Locations. Ned Levine & Associates, Houston, TX, and the National Institute of Justice, Washington, D.C, May.
- New York City Department of Health and Mental Hygiene (NYCDOHMH). 1994. Facts About Mold. Available online: <http://www.ci.nyc.ny.us/html/doh/html/epi/epimold.html>.
- New York State Department of Health (NYSDOH). 2002. Binghamton State Office Building: Post-occupancy environmental sampling, Final Round, October
- Skellam, J. (1946). The frequency distribution of the difference between two Poisson variates belonging to different populations, *J. of the Royal Statistical Society*, 10B: 257-261.

U.S. Department of Housing and Urban Development (HUD). 1995. The Relation of Lead-Contaminated House Dust and Blood Lead Among Urban Children. Final Report to U.S. HUD from the University of Rochester School of Medicine (Rochester, NY) and the National Center for Lead Safe Housing (Columbia, MD).

U.S. Department of Housing and Urban Development (HUD). 2001. National Survey of Lead and Allergens in Housing, Final Report, Volume I: Analysis of Lead Hazards, Revision 6.0. Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1990. *National Oil and Hazardous Substances Pollution Contingency Plan*. Final Rule 40 CFR 300. 55 Federal Register, 8666–8865, March 8. Washington, DC.

U.S. Environmental Protection Agency (EPA). 1994. Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities. OSWER Directive 9355.4-12. Washington D.C.

U.S. Environmental Protection Agency (EPA). 2001. Exposure and Human Health Evaluation of Airborne Pollution from the World Trade Center Disaster. External Review Draft. NCEA-W-1395. EPA/600/P-2/002A, October.

U.S. Environmental Protection Agency (EPA). 2003a. Interim Final WTC Residential Confirmation Cleaning Study. Volume 1. May.

U.S. Environmental Protection Agency (EPA). 2003b. Background Study Report. Interim Final. April.

U.S. Environmental Protection Agency (EPA). 2003c. World Trade Center Indoor Environment Assessment: Selecting Contaminants of Potential Concern and Setting Health-Based Benchmarks. Contaminants of Potential Concern Committee of the World Trade Center Indoor Air Task Force Workgroup. May.